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Low-energy house in Sisimiut – Measuring equipment

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Abstract

This paper documents the measurement equipment in a low-energy house in Sisimiut, Greenland. Detailed measurements are being taken on energy consumption, indoor temperatures, floor heating, ventilation, open/closed state of doors and windows, and indoors climate. Equipped with a central control unit, experiments can be designed in order to study heat dynamics of the building. It is described how to plan and execute such experiments in one apartment in the building. The building also features both a solar thermal system and extra buffer tank facilitating testing of storage strategies on the power generated by the solar thermal system. A weather station equipped with thermometer, pyranometer and anemometer is installed on the building as well. Finally, it is described how to retrieve data from an SQL server which is configured to take monthly backups. R functions have been implemented to fetch and prepare the data for time series analysis. Examples are given on the use of these.

Contents

1 Introduction

Technical University of Denmark (DTU) have constructed a modern low-energy house in Sisimiut, Greenland, in order to gain experience with low-energy construction even under very demanding weather conditions and creating a full-scale research facility that enables experiment with heating and ventilation systems. Furthermore, the house is equipped with solar thermal panels to provide domestic hot water. A picture of the building is shown in Figure 1. A thorough description of the building can be found in (Norling et al. 2006)

Figure 1 *A picture of the house taken from north-west. The guest apartment is to the left.*

After the first five years of operation, repair work was carried out in order to improve on the energy accounts of the house which did not live up to the original expectations. Moreover, it was decided to invest in an improved measurement and control system. The new system was installed in 2011 and provides more than 200 signals online to use for supervision and modeling of the building and the energy consumption. It can be used to execute experimental plans, and that even from remote.

This report is a description of the installed system and provides example plots of many important measurements. The report has been carried out partly for documentation of work done during a PhD study on heat dynamics in buildings, and hence the focus tend to be more on the part of the measurements that concern heating, temperatures, and occupancy. The house consists of two apartments of which one is rented out, and the other is used as a guest house and for research. Many of the examples from inside the building particularly uses data from the apartment that is not rented out.

Examples on experiments carried out in the building can be seen in (Andersen et al. 2013b). One of the experiments, from which many examples in this paper have been taken is thoroughly analyzed in (Andersen, Jiménez, et al. 2013). Finally, an analysis of some of the data that was collected before the installation of the new data acquisition system can be found in (Andersen et al. 2013a).

2 Overview of the system

All measurements in the building are collected by a central unit called a programmable logic controller (PLC). Measurements are taken on indoor climate, heating systems, the solar thermal system, outdoor climate, and presence of occupants. Table 1 shows an overview of the most important measurements for modeling of the heat dynamics of the building.

The PLC also provides a graphical user interface (GUI) for Microsoft Windows which is running on a computer in the house. This can be accessed from remote by using an application called Teamviewer[1]. From this, the most recent of many of the measurements can be seen. When opening the GUI, the user is being presented with an overview (See Figure 2) of the heating system, and the solar thermal system. Leaving the boiler ("Oliefyr") the heated liquid is first connected to the domestic hot water tank (where the liquid can run through a spiral without mixing with the water in the tank), then to the floor heating loops, and finally to the ventilation after heating. Only 6 floor heating loops are shown in the overview, but actually there are 12 of them. The return temperatures are reported individually while the forward temperature is common for all of them. The water from the boiler is connected to the ventilation intake air through a heat exchanger. The ventilation system is equipped with heat recovery so the boiler is only used to heat after that.

The solar thermal system is connected to the domestic hot water tank. If all the water in the tank is already hot, the liquid can be passed to a buffer tank under the building or it can be run through a heat exchanger to after heat the liquid coming back to the boiler. If also this tank is hot already, and there is no use of the energy in the heating system, energy from the solar system can be dispatched in a radiator located in the entrance hall.

All data is being collected using the PLC system in UTC time. Normally, data is being measured every 30 seconds or with pulse signals. Table 4 in Appendix A is an overview of all the sensors, and basic information about them. An overview of the computer network in the building is given in Appendix B.

[1] `http://www.teamviewer.com`

Table 1 *Overview over measurements in the house of special interest for modeling of heat dynamics of the building.*

Measurement	Common areas	Rental apartment	Experimental apartment
Temperature	Hall Broiler room	All rooms	All rooms Full standard indoor temperature measurement in living room
Heating			
Floor heating	2/2	5/5	5/5
Ventilation afterheating		All measured together	
Ventilation			
Central ventilation		All measured together	
Outer doors open/closed	2/2	3/3	3/3
Windows open/closed	No windows	2/2	2/2
Cooker hood	0/0	0/1	1/1
Occupancy			
PIR sensors	0	0	Living room/kitchen, corridor
CO_2 concentration	0	Deactivated	Yes
Consumption			
Oil		All measured together	
Electricity	1/1	1/1	1/1
Solar thermal system		Only one system	
Total heat collection			
Domestic water heating			
Buffer water heating			
Heating system		Contributes to common system	
Metereological variables		All at one common weather station	
Ambient temperature			
Solar radiation			
Wind speed			
Wind direction			

3 Consumption measures

The consumption in the building is measured in terms of oil consumption, electricity consumption, and water consumption. Electricity consumption is measured for the two apartments and for common spaces separately. The water consumption is measured for the whole building. The PLC GUI provides the overview of online consumption readings shown Figure 3.

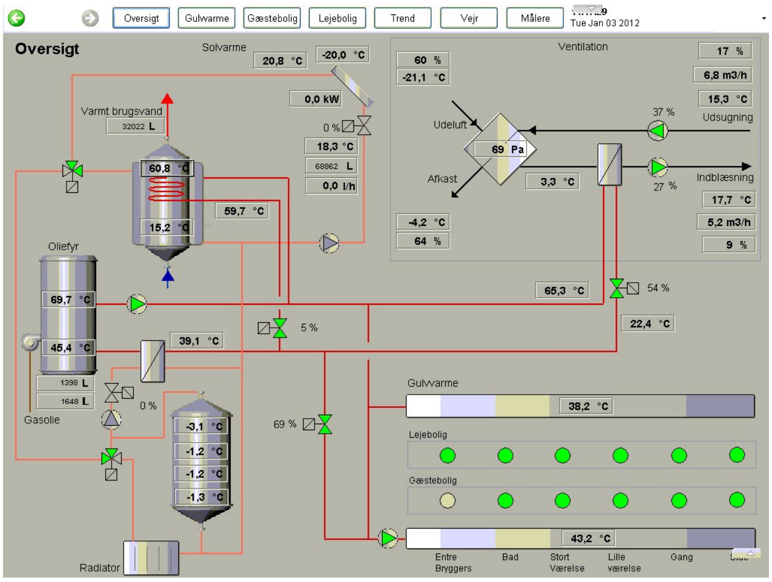


Figure 2 *Overview of the flows in the PLC graphical user interface.*

3.1 Oil consumption

Three readings, `A02_FM01`, `A02_FM01_SUM`, `A02_FM01_TRIP`, are measurements of the oil consumption. `A02_FM01` and `A02_FM01_SUM` are plotted for the year 2012 in Figure 4. `A02_FM01` seems to always be 0 and hence contains no information. The others are cumulative counts of pulses for each liter of oil that has been consumed, so the resolution is quiet limited. The "trip" version can be reset in the user interface but is apart from that exactly the same as the "sum". However, it seems to be missing in the database. From the data, it is calculated that about 2930 liters of oil were consumed in 2012.

3.2 Electricity consumption

The readings from the three electricity meters in 2012 are shown in Figure 5. The meters get a pulse for each kWh consumed. As, expected, the rental apartment has the larger electricity consumption. It is quite stable, but larger in the winter than in summer. The guest apartment electricity consumption comes more in jumps which is normal because of the occasional use. The common electricity consumption seems to be quite constant over the year. Again, that is as expected since this is mostly for pumps, data acquisition, a computer etc.

It is known that at least a freezer belonging to the rental apartment has been connected to a power plug socket of the common areas. Thus, the measures may not exactly correspond to what is expected.

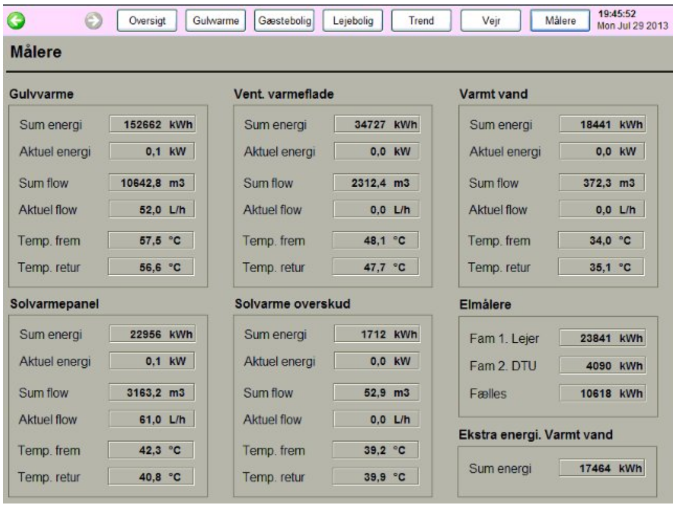


Figure 3 *The PLC GUI overview of consumption measures. The headlines are (row wise) "Floor heating", "Ventilation heating", "Hot water", "Solar thermal panel", "Excess solar power", "Electricity meters", "Extra energy, hot water".*

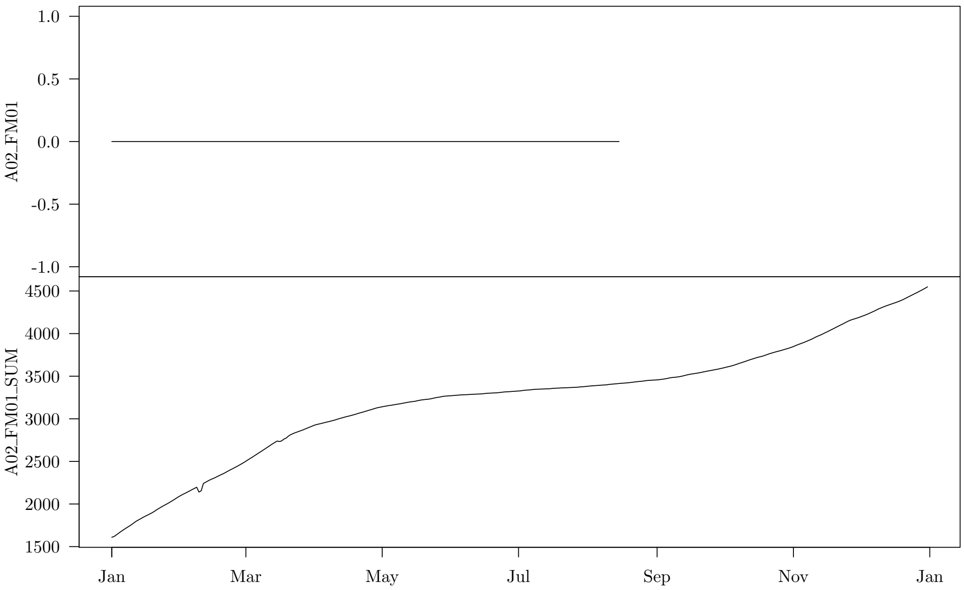


Figure 4 *The two available series related to the oil consumption throughout 2012. The instant flow measurement is obviously not working, and the "Trip" series is missing in the database.*

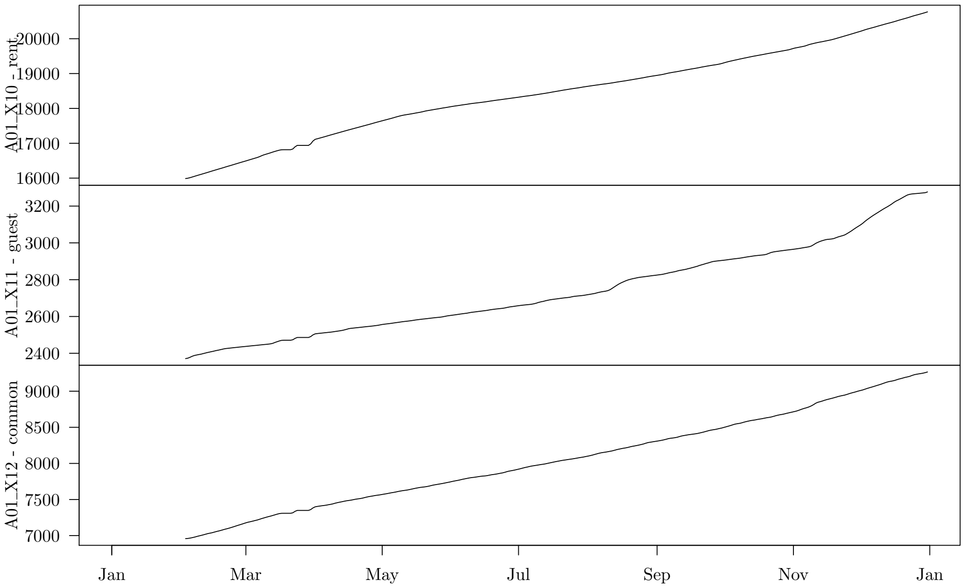


Figure 5 *The three electricity meters throughout 2012.*

3.3 Water consumption

A flow measurement from boiler to spiral in domestic hot water tank is missing. Hence, the power consumption to hot water cannot be calculated. The description of the water consumption is therefore incomplete.

The water consumption is being measured in terms of water flows and energy consumed for water heating. Also the temperature of the water near the bottom and near the top of the hot water tank is being measured. Some related data is plotted for 2012 in Figure 6. The first plot is the total energy to domestic water heating. The two next plots are the average daily consumption in m^3/h and the cumulative consumption in m^3. Figure 7 compares these two signals by cumulating the instant flow (A04_X02) to the cumulative flow (A04_X03) subtracted by its own minimum. They obviously match except for periods of missing flow measurements. A04_X02 is called an instant power measure in the database. This must be a mistake. It must be a flow measure.

The fourth plot in Figure 6 is apparently an instant volume flow (A04_X04). The mean value is around 230. What it represents is unknown, and so is the unit. According to Bo Holdt-Simonsen, it is likely to be a power measure. Then follows a water inflow temperature. The temperatures are too low to be from the boiler and seemingly too high to be from the solar panel. A04_X10, A04_FM01, and A04_FR01 are missing or zero and do not contain any information. A04_X11 is cumulative extra energy to hot water, i.e. the energy to hot water consumption not covered by the solar thermal panels.

In 2012 the increase is larger than for A04_X01 which further questions what the latter represents.

The cumulative hot water flow from the tank – A04_FM01_SUM – has a few outliers. Even though it seems to be in liters, it seems to have similar shape to A04_X03 which is the cold water inlet to the tank. They are compared in Figure 8 and and match very well.

4 Room temperature measurements

The temperature is measured in each room by Thermokan SR04 wireless sensors. The sensors have two parameters to control the frequency with which they transmit measurements. The one is T_{wakeup}, the number of seconds between each measurement. If a measurement is more than 2% different from what previously recorded, a signal is transmitted. This condition is repeated T_{interval} times after which a signal is transmitted no matter the measurement. T_{wakeup} and T_{interval} are both set to 10 seconds. That means that a signal is sent at least every 100 seconds. Adjustment of these variables is done by physically moving jumpers under the plastic covers on the units.

The sensors are installed on the walls around 150 cm from the floor. A sketch of the positions and pictures of one of the sensors are shown in Figure 9.

4.1 Standard room temperature measurement

Placed centrally in the guest apartment, a column of six temperature measurements is installed. They are thermocouples type T sensors with Seneca K121 transmitters. See pictures and a sketch of the position heights in Figure 10.

Figure 11 shows different temperatures measured in the building. The upper plot shows temperature measurements in the different rooms of the apartment, measured by on-wall thermometers. The temperature difference between some rooms are up to about 5 °C. Another interesting feature is that when the temperatures increase rapidly, the living room temperature seems faster than the others. There are however also times where this is not the case. This could indicate that different heating inputs (e.g. floor heating and solar radiation) work differently on the different rooms.

The second plot in Figure 11 shows temperature measurements from the column of standardised temperature measurements located centrally in the apartment. The temperature difference from top to bottom stays within a couple of °C, and the temperature gradient switches direction when the sensors are being heated or cooled respectively. When they are cold, the bottom

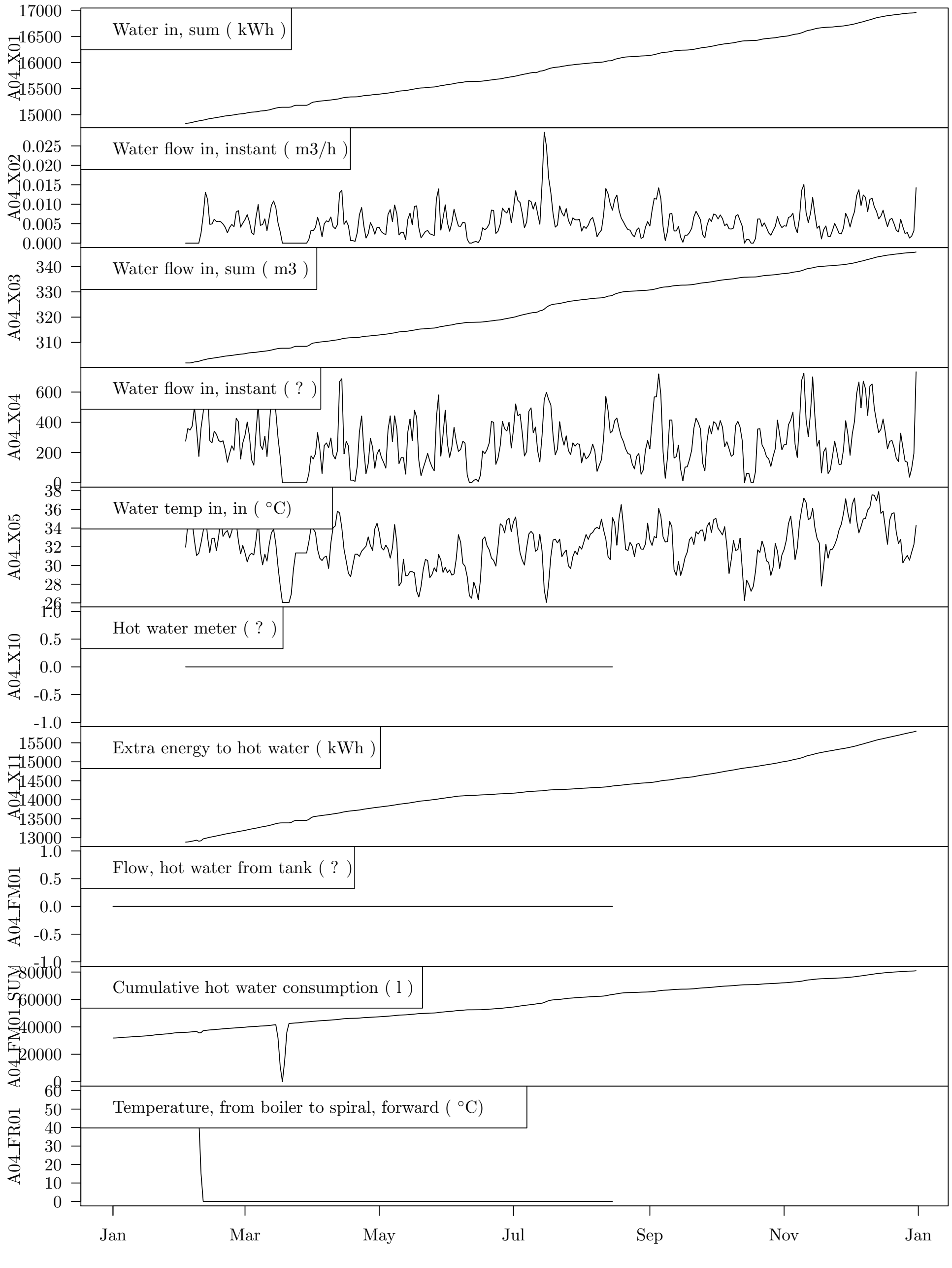


Figure 6 *Measures related to water consumption.*

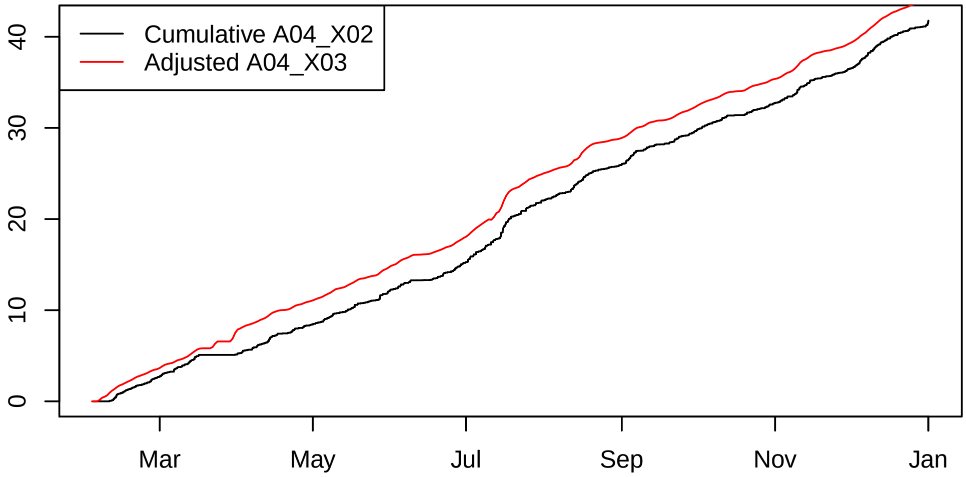


Figure 7 *Comparrison of A04_X02 and A04_X03 where the first has been cumulated, the latter has been substracted its minimum.*

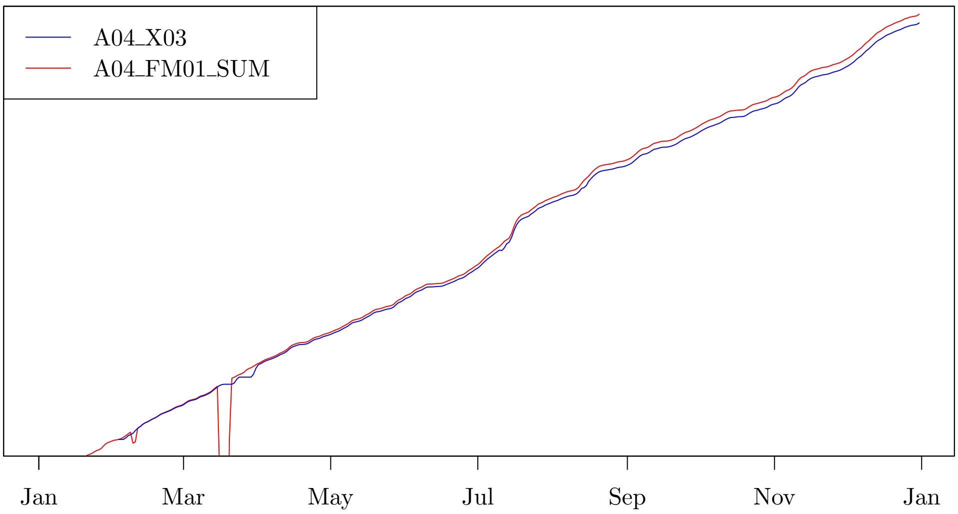
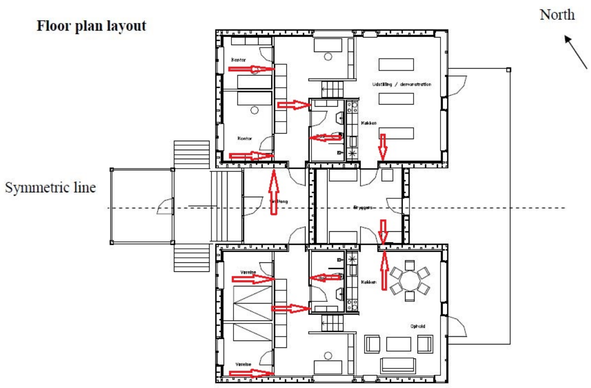
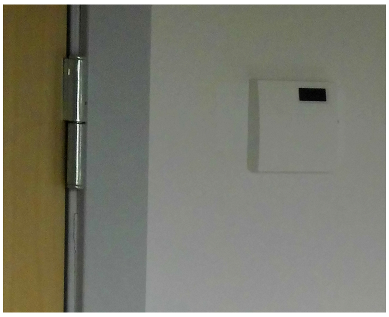


Figure 8 *Comparisson of the cold water inlet and the hot water outlet from the domestic hot water tank. The signals have been scaled to match.*



(a) *The positions of the thermal sensors used to control the floor heating.*



(b) *An installed thermal sensor.*

(c) *A thermal sensor with cover removed. The jumpers are seen in the bottom-left corner.*

Figure 9 *Positions and pictures of the thermal sensors that are installed in all rooms except for the boiler room. Sketch and photots by Konstatinos Tsapralidis*

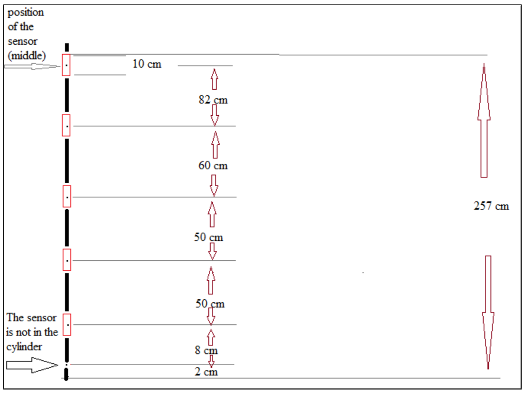
measurement is the lower, when they are warmer, the top measurement is the warmer.

4.2 Principal component analysis of temperature distribution

Principal component analysis (Izenman 2008) is a method in multivariate statistics where the variation in multiple directions (here multiple sensors) is projected onto new orthogonal dimensions. These new dimensions are ordered so that the first (principal) component captures the most of the variation in data, the second component captures second most under the constraint to be orthogonal to the first and so on. This method will now be

(a) *The whole column of thermometers.*

(b) *One sensor in the column.*



(c) *Sketch of the heights of the sensors.*

Figure 10 *The column of temperature measurements in the presentation apartment. On (a) the cooker hood, the C0_2 sensor (near the ceiling to the left of the column of thermometers), and a PIR sensor (in the ceiling in the back) are also seen. 10c shows the heights of the six sensors (Konstatinos Tsapralidis).*

applied to the data shown in Figure 11 which is a period where synchronous floor heating has been applied to the rooms in the guest apartment. This is called Experiment 1 in (Andersen et al. 2013b).

The loadings are shown in Figure 12 and express how the original measurements are weighted in the construction of the principal component. This means that the principal components are linear combinations of the original temperature measurements.

Figure 13 shows principal components of both the room temperatures and the temperatures measured in the column of sensors. It is seen that the first principal component in both cases represent something close to the mean

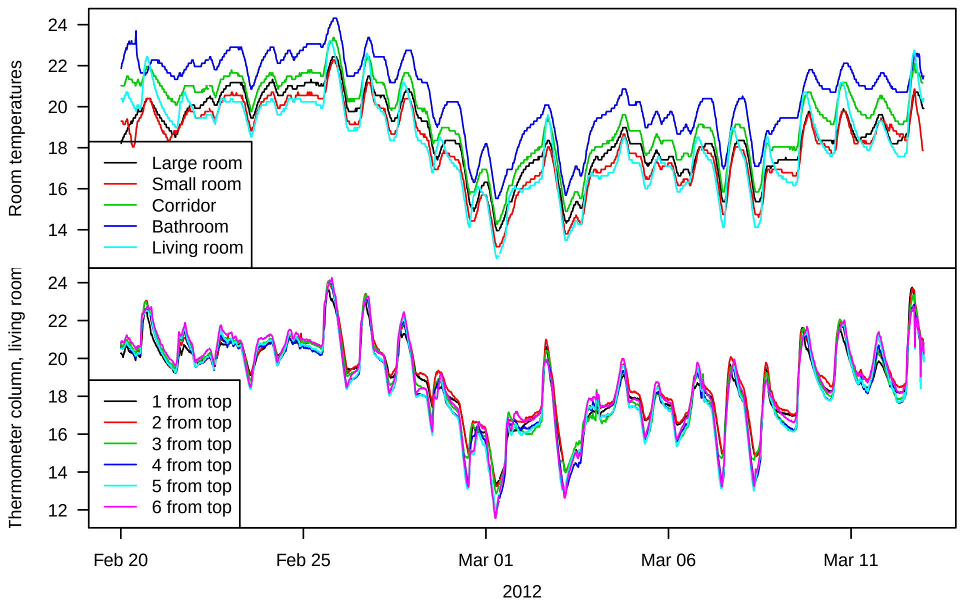


Figure 11 *Different temperatures measured in the guest apartment.*

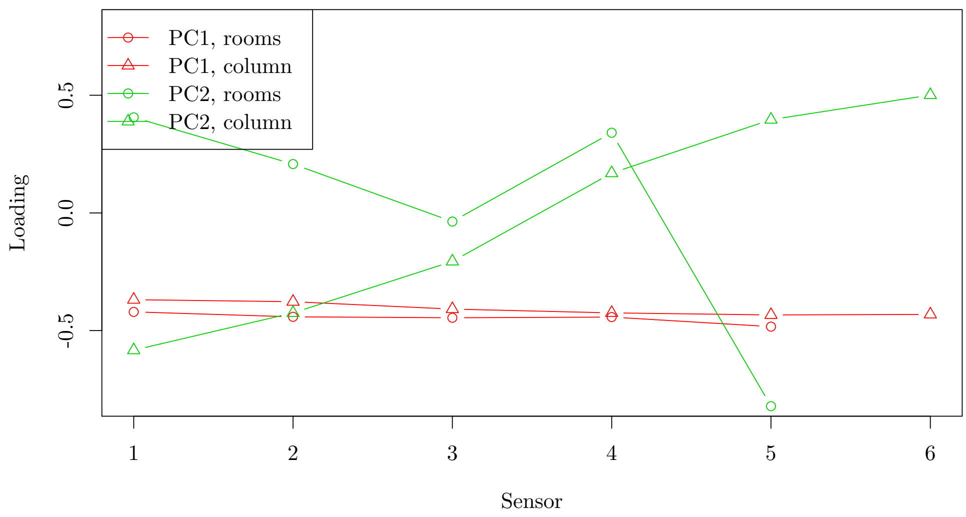


Figure 12 *Loadings of the different temperature measurements in principal components. For the column, the number on the abscissa means the sensor number from the top. For the rooms, the sequence is large room, small room, corridor, bathroom, living room.*

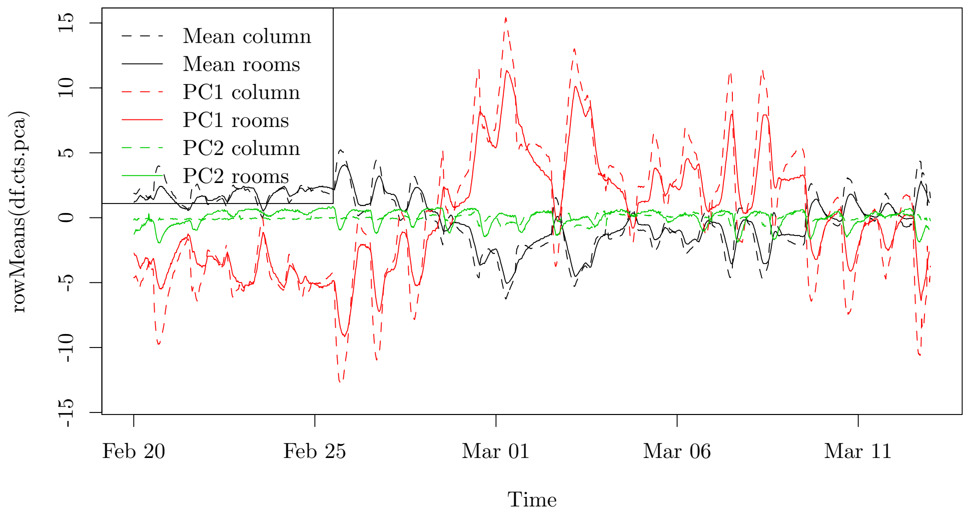


Figure 13 *Averages, first and second principal component.*

values of the groups of temperatures (with negative sign). The second principal component expresses the difference from top to bottom. The warmer the bottom is compared to the top, the larger this principal component. Furthermore, the measurements have the larger weight, the further they are from the center. For the rooms, the second principal component expresses the temperature difference between the living room on the one side and the two rooms and the bathroom on the other. Notice that the corridor is given approximately zero weight.

So the second component of the column of thermal sensors expresses the vertical temperature gradient. This dynamics is important because it is excited by floor heating. The second component of the room temperatures expresses the difference between living room and small rooms plus bathroom. This is likely to be because of the solar radiation coming into the living room through the large windows.

This is an example of how principal component analysis can be used to analyze spatial heat dynamics in a building.

5 Activity sensors

The house is equipped with different sensors with the purpose of facilitating analysis of the influence of user behavior in models of heat dynamics. Open/closed sensors are on all external doors and windows of the two apartments and the common exterior doors. Moreover, the guest apartment has two passive infrared (PIR) sensors and a CO_2 sensor to measure presence of occupants. This section briefly lists the available measurements and gives an example of recorded data from a short period. Through the GUI of the PLC, an overview of each apartment can be seen. A screen dump of this is shown for the guest apartment in Figure 14. In the overview, the user can see temperature measurements, status of floor heating (green disc for on, white for off), set temperature for floor heating, and PIR sensor status (see Section 5.1). The six temperatures to the left are from the column of thermometers in the center of the apartment followed by temperature and humidity measurements in paper insulation under the house. Open/closed state of windows and doors is also seen in the overview (Section 5.2).

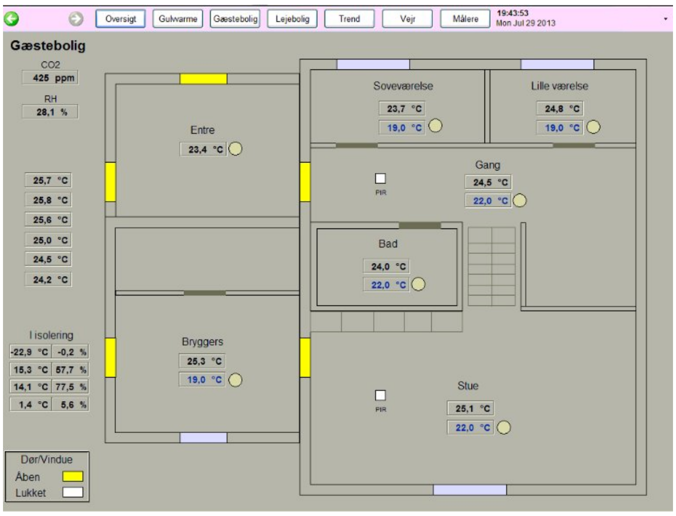


Figure 14 *From the PLC GUI an overview of the activity in the two apartments can be seen. In the guest apartment, as shown here, CO_2 concentration is measured in the living room, and two PIR sensors register occupant presence.*

5.1 Passive infrared sensors

In the rental apartment two passive infrared (PIR) sensors are installed in the ceiling. One is in the corridor (see Figure 10a), one is in the living room. They have a delay of less than one minute, meaning that they will keep showing activity for this delay after activity has been measured.

(a) **(b)**

Figure 15 *Two passive infrared sensors are installed in the guest apartment. The one in the living room is seen in the ceiling in the picture to the right. See the position of the one in the corridoor in Figure 10a. Photos by Konstatinos Tsapralidis.*

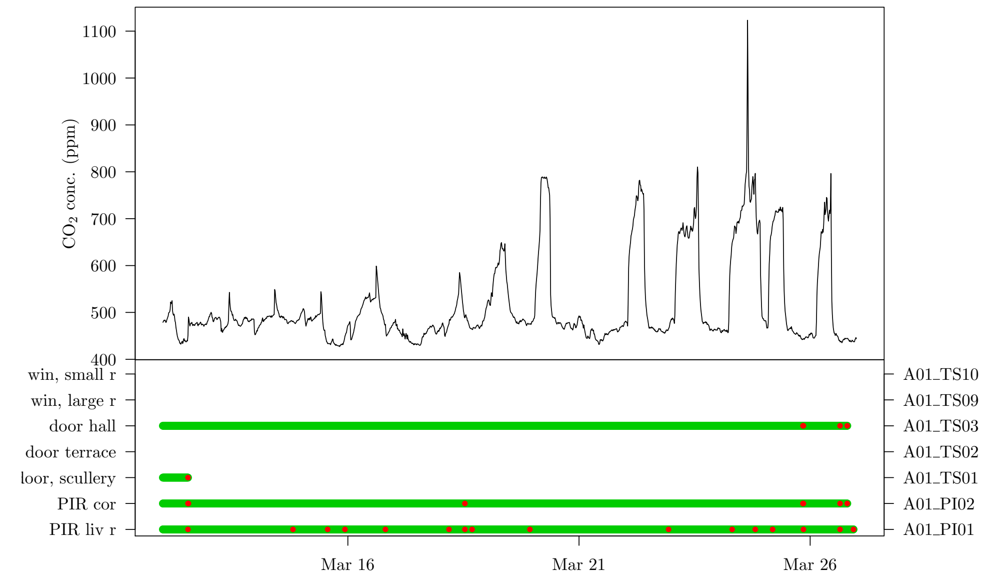


Figure 16 *The occupancy sensors in the guest apartment during experiment 5.*

5.2 Open/closed sensors

The outer doors of the building (entrance door, backdoor), and outer doors and windows of the apartments (doors to hall and scullery, windows and terrace door) have open/closed sensors.

5.3 CO_2 sensors

There is a CO_2 sensor in each apartment (see Figure 10a), but only the one in the rental apartment is active. This and the missing PIR sensors in the rental apartment is due to respect for privacy of the tenants.

5.4 A short period of data

Figure 16 shows data from the PIR sensors, the open/closed sensors and the CO_2 sensor in the guest apartment from March 12th to March 27th 2013. Green is a closed door or no activity while red means open door or activity. The data logger stops logging when there is no change in the signal, which is the reason for the white spaces. It has been checked that they correspond to no activity or closed as well as green.

It is noticed that the PIR sensors react even though no doors have been opened. It seems that something else than occupant presence is able to activate them or that the open/closed sensors do not work. The CO_2 measure does not seem to be a good indicator of activity. It is periodically all large but this does not seem to be correlated with the other signals.

6 Floor heating

The floor heating system is liquid born and has twelve strings, including five for each apartment, one for the entrance hall, and one for the scullery. One common forward temperature is measured. For the return temperatures, both a common return temperature, and the twelve individual return temperatures are measured.

Figure 17 *Overview of the floorheating in the PLC graphical user interface.*

This means that the floor heating supply to the i'th string can be calculated as

$$P_{\mathrm{h},i} = c_{\mathrm{h}} \cdot \rho_{\mathrm{h}} \cdot \dot{V}_{i,\mathrm{h}} \cdot (T_{\mathrm{h,in}} - T_{i,\mathrm{h,out}}) \tag{1}$$

$P_{\mathrm{h},i}$ is the power dispatched in the i'th string, c_{h} is specific heat capacity of the liquid, ρ_{h} is the density, $\dot{V}_{i,\mathrm{h}}$ is the volume flow through the i'th string, $T_{\mathrm{h,in}}$ is the common forward flow temperature, and $T_{i,\mathrm{h,out}}$ is the i'th return temperature. However, some resampling may be needed to obtain common time stamps for the involved signals. How to obtain this will be described in Section 12.4. The flow and temperature sensors on the floor heating system are shown in Figure 18. Status of valves in the twelve strings and the inflow pump are logged as well.

The constants c_{h} and ρ_{h} are specific heat capacity and density for the fluid in the floor heating system which is a mixture of water and glucola. Liquid has been added multiple times resulting in an unknown ratio of the two components. A Nuclear Magnetic Resonance Spectroscopy (NMR) analysis of a sample of the liquid was performed at Department of Energy Conversion and Storage at Risø, DTU. The mixture was estimated to be 1:8.85

of glucola/water by molecular concentration. The estimate should have an uncertainty of around 5%. This ratio can be used to estimate the heat capacity and the density of the mixture. A linear interpolation using this concentration yields $c_{\mathrm{h}} \approx 4.01 \cdot 10^3\ \mathrm{J\,kg^{-1}\,K^{-1}}$ and $\rho_{\mathrm{h}} \approx 1.01 \cdot 10^3\ \mathrm{kg/m^3}$.

Figure 18 *Return temperature and flow measurements on floor heating strings. Flow measurements are before the strings, temperature measurements after. The combined forward temperature is measured by the thermometer at the end of the red wire between the lids marked "1" and "2".*

As an example, floor heating data from an experiment in the guest apartment is shown. Since there are five floor heating loops with individual flow and return temperature measurements (common forward temperature measurement), the example involves 11 signals. The experiment was designed so that the five floor heating signals followed a common Pseudo Random Binary Signal (PRBS) which is a deterministic powerful signal for examples to identify and infer on dynamic systems (Godfrey 1980). The flow measurements are shown in Figure 19. It shows both the total flow and the flows for the individual rooms. The total flow is only shown interpolated, the individual ones are shown both as raw measurements, and interpolated. This is due to measurements not always being taken at the exact same time, so the sum of the individual measurements is not well defined. In the bottom, the PRBS used for the experiment is shown.

Figure 20 shows the return flow temperatures in the five floor heating loops. Also it shows their mean at each interpolated time step. The total floor

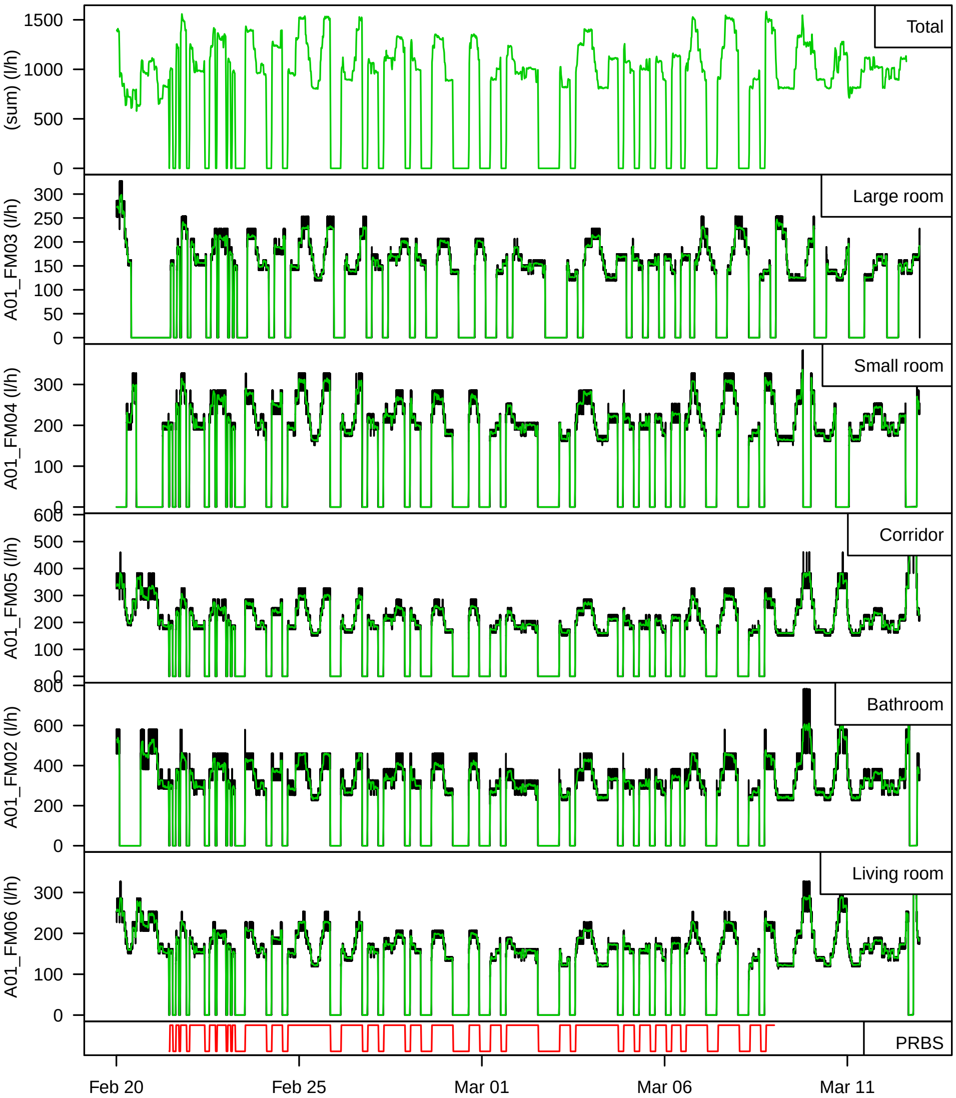


Figure 19 *Flow measurements and interpolations of these in all floor heating loops in the apartment. The black points are raw data, the green are interpolated.*

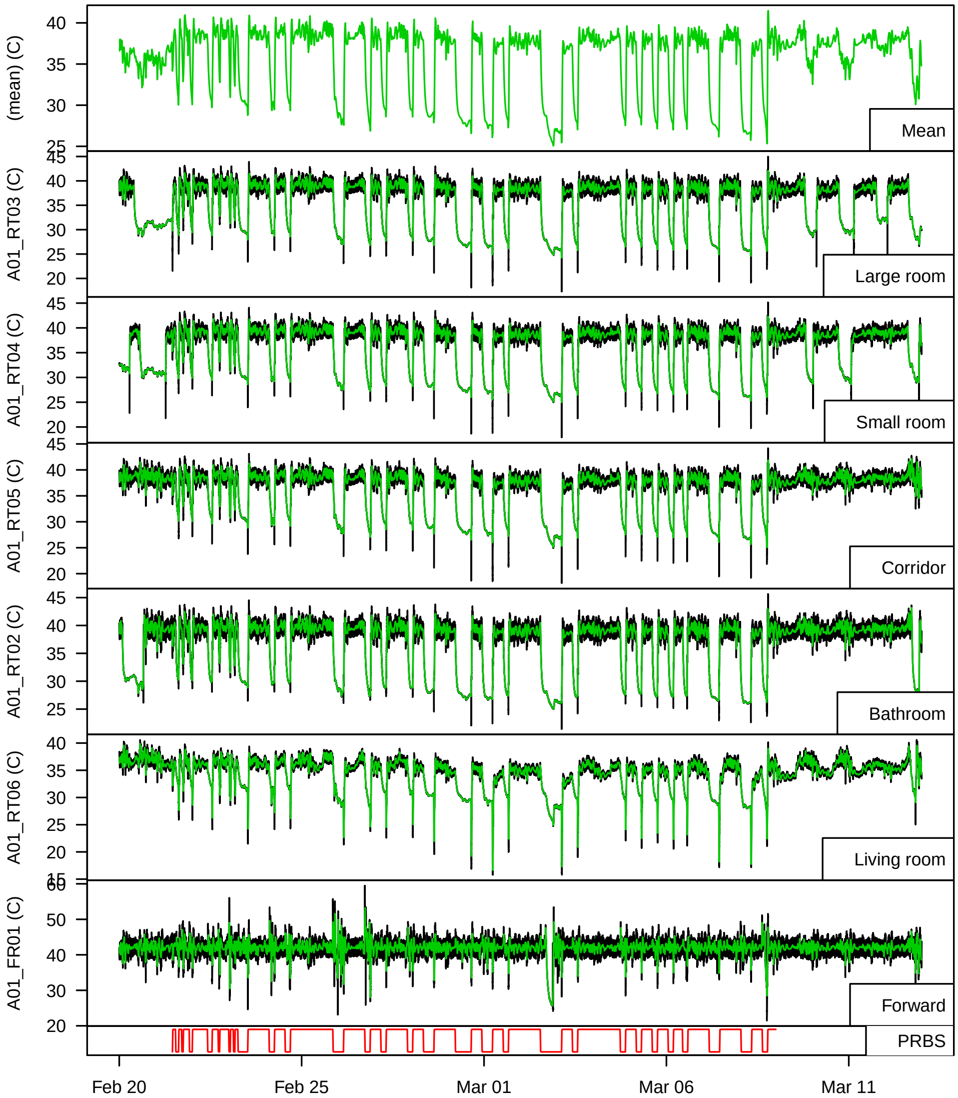


Figure 20 *Return temperatures and interpolations of these in all floor heating loops in the apartment. The black points are raw data, the green are interpolated.*

heating power to the apartment is now estimated by

$$P_{\mathrm{h}} = \sum_{i=1}^{5} P_{\mathrm{h},i} \tag{2}$$

This is plotted together with the estimated power in the individual loops in Figure 21.

Figure 22 shows the distribution of the energy supplied to the floor heating system in the guest apartment during the experiment. In total, 1291 kWh is supplied.

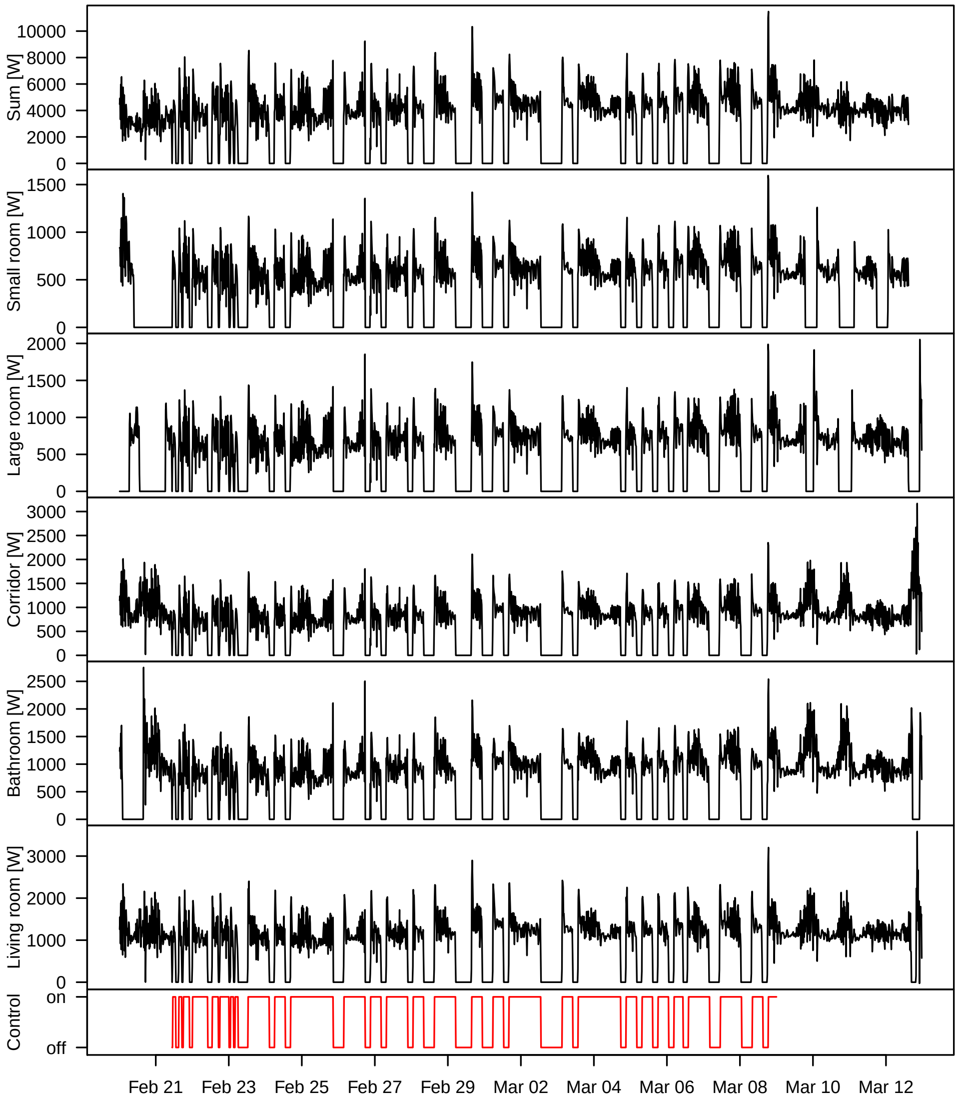


Figure 21 *The estimated floor heating power supplied to the guest apartment.*

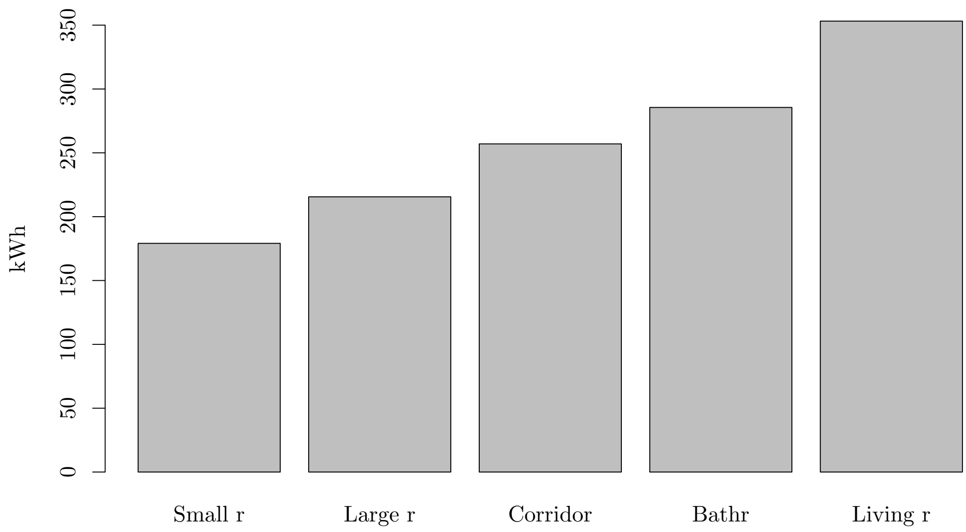


Figure 22 *The distribution of the floor heating supplied to the guest apartment during the experiment.*

7 Ventilation

For a description of the ventilation system, see e.g. (Vladyková et al. 2011). Here, the focus is on the describing the location of the sensors. Both flows and temperatures are measured different places in the ventilation system. However the contribution to the whole building is measured, not to the apartments individually.

A sketch of the ventilation system and the positions of the different sensors is shown in Figure 23.

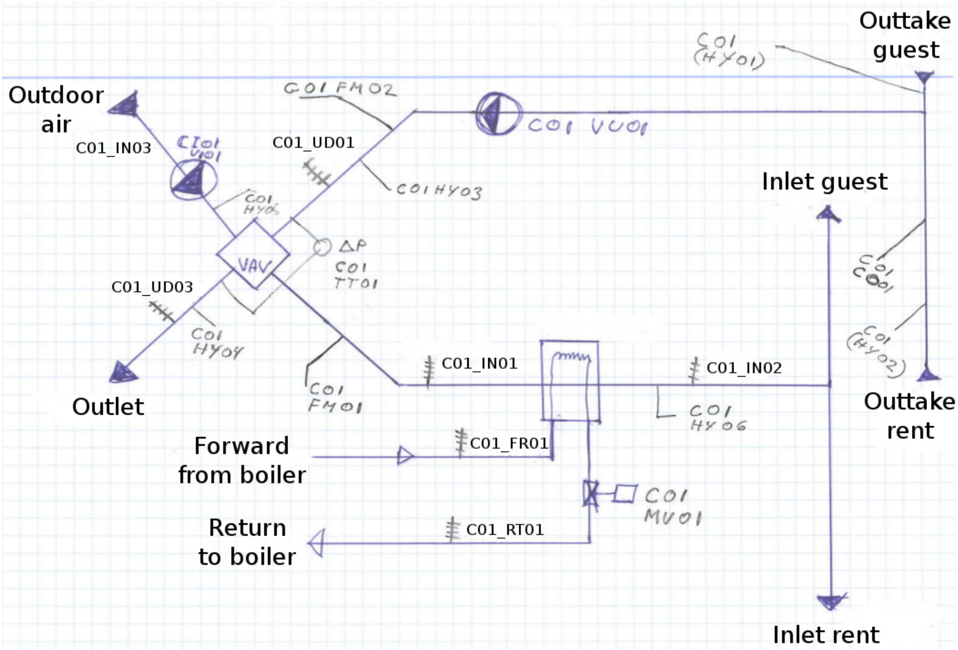


Figure 23 *Sketch of the ventilation system and the position of the sensors. By Bo Holdt-Simonsen and Philip Delff.*

The flow measurements are being calculated in the PLC from a pressure drop measurement using the relation

$$Q = 27,8 \cdot \sqrt{\Delta p} \cdot 3.6\text{m}^3/\text{h}/\text{Pa}^{1/2} \tag{3}$$

However, until March 30 2012 the following relation was erroneously used:

$$Q = 0.5\text{m}^3/\text{h}/\text{Pa} \cdot \Delta p \tag{4}$$

For data before March 30 2012, the user has to correct the data.

Figure 24 shows ventilation in and out flows for a period in February-March 2012 (the data has been corrected to follow Equation (3)). The in flow stays in the interval 4 to 11 m^3/h while the out flow stays within 6 to 10 m^3/h.

The cumulative flows show that the out flow is considerably larger than the in flow on average.

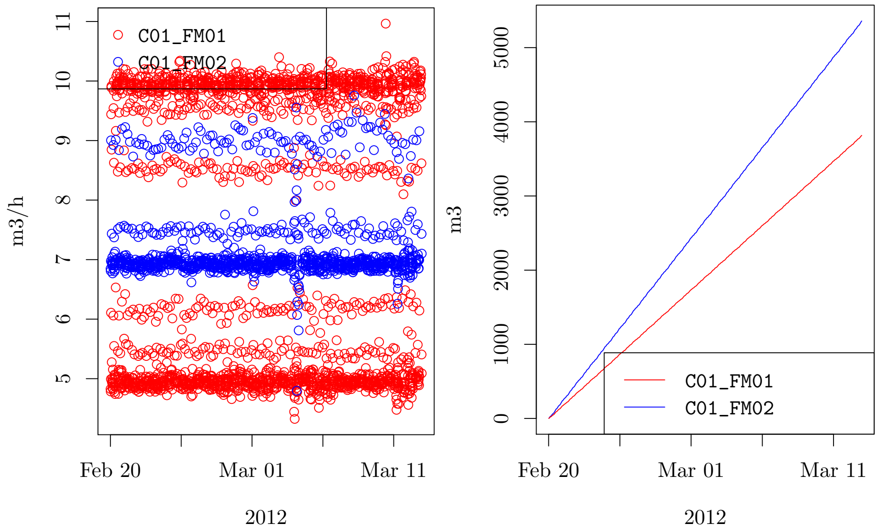


Figure 24 *In flow is red, out flow is blue.*

Flow temperatures in the ventilation system are plotted in Figure 25. The inlet temperature to the building varies little around 22°C. The inlet before any heating follows the outdoor temperature, while the outlet temperature follows the indoor temperature.

The energy supplied to the building by the ventilation system is estimated and plotted in Figure 26. It is estimated based on inlet temperature after the after heating, outlet temperature before heat exchanger, in and out flows, and physical properties of air at 25°C. The relation is

$$P_{\mathrm{v}} = c_{\mathrm{air}} \cdot \rho_{\mathrm{air}} \cdot (\dot{V}_{\mathrm{v,in}} \cdot T_{\mathrm{v,in}} - \dot{V}_{\mathrm{v,out}} \cdot T_{\mathrm{v,out}}) \tag{5}$$

The power supplied will be negatively correlated with indoor temperature according to Equation (5).

7.1 Cooker hoods

The use of the cooker hoods are measured in both apartments. The data can be found under the tags `C01_TT01` and `C01_TT02` respectively.

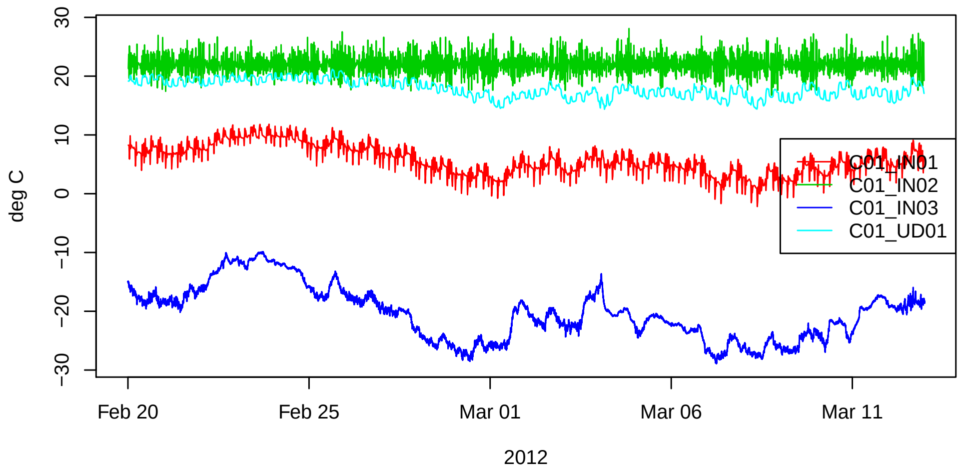


Figure 25 *Temperatures in the ventilation system. C01_IN03 is inlet before any heating, C01_IN01 is inlet after heat exchanger, before after heating, and C01_IN02 is inlet after after heating. C01_UD01 is outlet temperature from the apartment, before heat exchanger. See also Figure 23.*

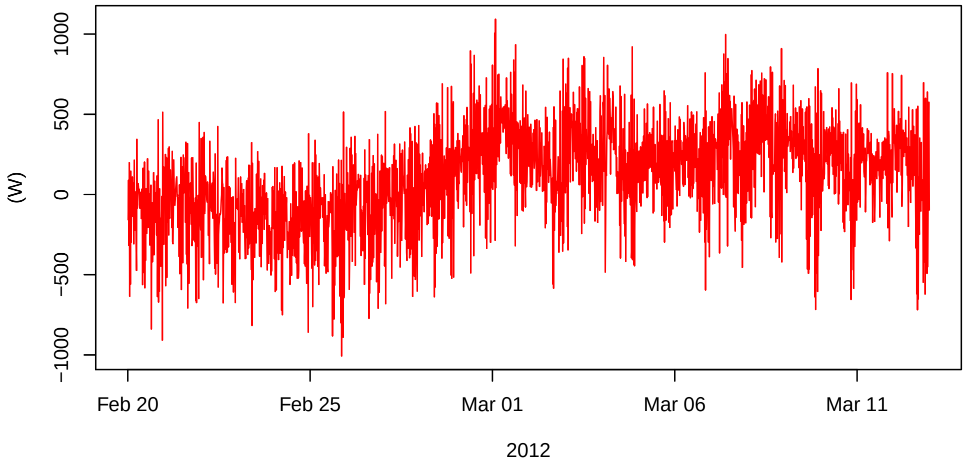


Figure 26 *Estimated ventilation energy to the building. Based on C01_IN02, C01_FM01, C01_UD01, C01_FM02, and physical properties of air at 25*°C.

8 Weather station

The building is equipped with a weather station connected to the data acquisition. The weather station includes a thermometer which is shielded from radiation, a pyranometer measuring global horizontal radiation, and an anemometer measuring both wind speed and direction. On the picture in Figure 1 the weather station is seen on the roof. Figure 27 shows the overview provided by the PLC GUI. Apart from online measures, it provides dynamic graphs where the user can specify time interval and which measures to plot.

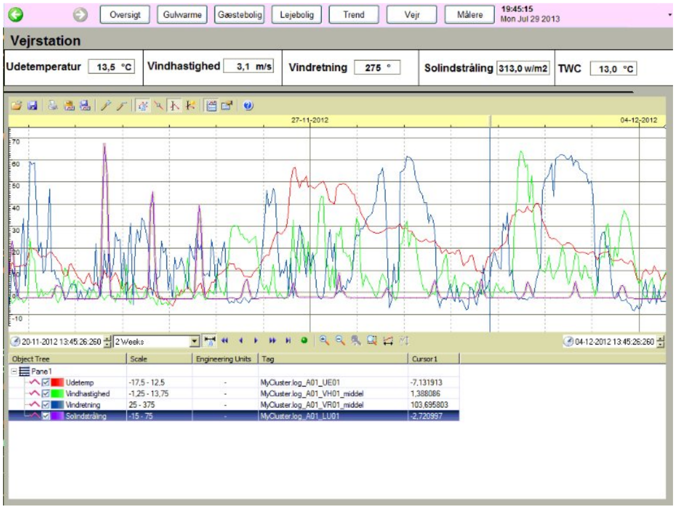


Figure 27 *The weather overview in the PLC GUI. In the bar just under "Vejrstation" (Weather station) are outdoor temperature ("Udetemperatur"), Wind speed ("Vindhastighed"), Wind direction ("Vindretning"), Solar radiation ("Solindstråling"), and the temperature with chill factor ("TWC").*

Data from the weather station in the period January 16th to February 1st 2013 is shown in Figure 28. The data shown has been averaged to 15 minute resolution. The outdoor temperature increases by more than 10 °C within about half an hour. That happens as a the wind speed picks up from about 0 to 12 m/s with wind speeds up to 20 m/s to follow. The wind direction is remarkably steady in this period. Notice about the spikes in the wind direction that most of them correspond to a very small angle change around North. Moreover, when interpolating directions the angles have been split in sine and cosine, interpolated, and then the angles have been re-calculated. Interpolating 0 and 2π to π would obviously be wrong.

The pyranometer has the limitation of only being able to measure radiation of angles of incidence lower than 82°. Also, notice that the readings from the pyranometer go well under 0 W/m^2. This must be calibrated before using the data. In general, this offset seems to be drifting, so for each data set, a parameter for this has to be estimated.

The red curves in the plots are 10 minute mean values provided in the database. Because of the averaging done here, they are almost the same as the plot of the raw measurements. There is supposed to be an outdoor temperature adjusted by a "chill factor" in a signal called "TWC" in the database, but the signal is missing.

Figure 28 *Data from the weather station from January 2013. The period features an extreme temperature change on January 21st followed by a storm. Notice that the pyranometer seems badly calibrated.*

9 Solar thermal system

The building features a solar thermal system providing energy for hot domestic water usage. The system is treated in (Dragsted 2011).

Figure 29 *The solar thermal panels on the low-energy house (Dragsted 2011).*

The system consists of six panels totalling an area of 8.31 m^2 (See Figure 29). They are tilted 70° from level, and the orientation is 124° clockwise from North.

Temperatures and flows between the solar panels, the hot water tank, the buffer tank, and the radiator are measured. Also, an entry in the database contains the power produced by the system. The daily mean of this power has been calculated and plotted for 2012 in Figure 30. Apparently, either the system or the data logging was not working the first 5 months of the year and maybe from November again. Moreover, the power is sometimes negative. It should be cleared what exactly this measures before using it.

As sketched in Figure 2 the pipes from solar thermal panels go to the a heat exchanger in the domestic hot water tank. In case that the water in the hot water tank is already sufficiently warm, the water can be lead to a buffer tank or a radiator. At the time when (Dragsted 2011) was written, the buffer tank was not installed, and the surplus of hot water would go to the radiator. The radiator has been installed inside the house and then moved out because it was heating too much during summer. The buffer tank which is well insulated and located under the house is supposed to facilitate

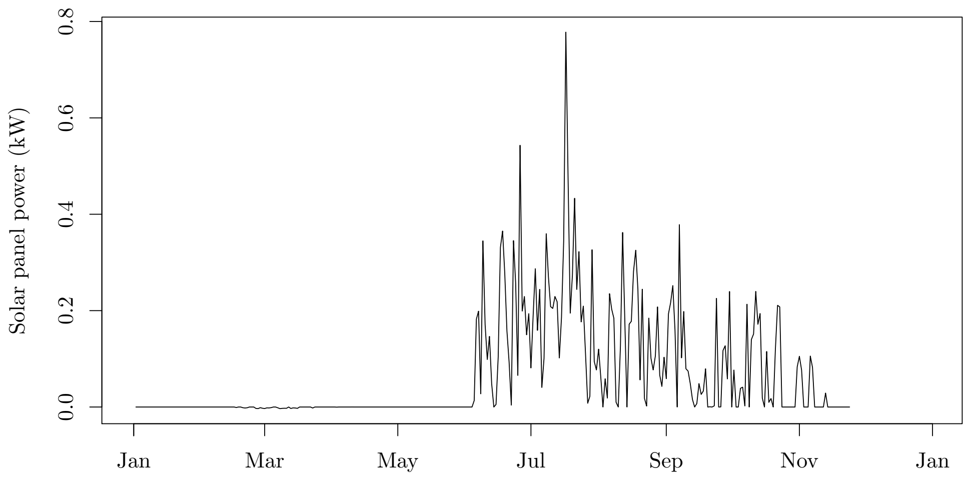


Figure 30 *The power produced by the solar thermal panels throughout 2012.*

keeping the hot water longer so the radiator is no longer needed. It was installed in April 2011 and has a capacity of 800 l. It is designed so that hot and cold water mixes minimally.

The temperature is measured at four heights in the tank. The four temperature measurements are plotted for 2012 in Figure 31. As expected the temperatures are higher in summer, and the temperature is generally increasing from bottom to top. However, the temperature curves do not go lower than -3°C and -1°C. This could be because of settings of the sensors or the data acquisition. But it should be checked whether these temperatures are actually representative. Also a maximum temperature of 10°C seem low.

According to Bo Holdt-Simonsen, the buffer tank has probably never been in use in the system.

10 Data logging

This section describes the overall Building Management System (BMS) installed in the building.

10.1 Network overview

The BMS system consists of a PC, on which SCADA software to monitor and log data is installed. The PC is connected to a local TCP/IP network on which the PLC and the router also are connected. The router is also connected to the internet for remote access. An network overview is found in Appendix B

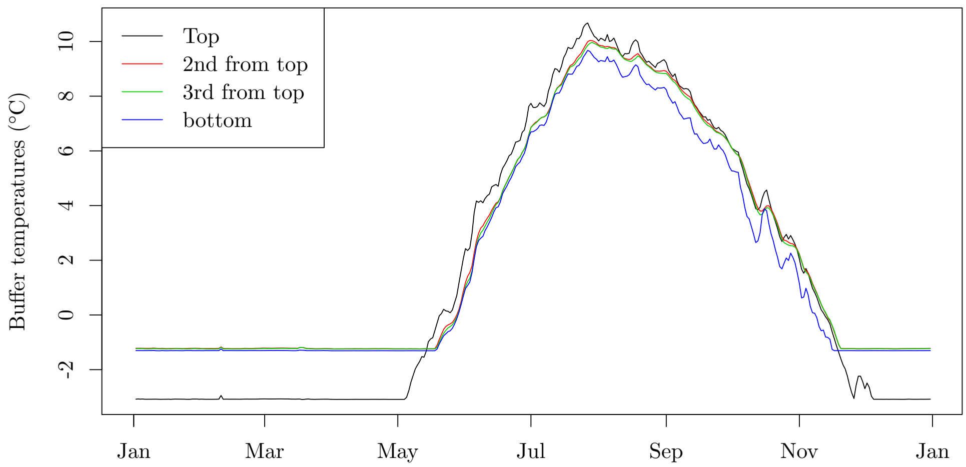


Figure 31 *The temperatures at four different heights in the buffer tank throughout 2012.*

10.2 Data acquisition hardware

The data acquisition hardware consists of the following:

- Schneider TSX P57 2634M Premium PLC [Programmable logic controller]
  - IO modules [Physical In and Out put modules for direct connected sensors and actuators]
- Thermokon SRC65 ModBus to Wireless gateway [Gateway between PLC and wireless sensors]
  - Thermokon wireless sensors
- RESI ModBus to MBus gateway [Gateway between PLC and M-Bus meters]
  - Kamstrup and Brunata energy meters

The PLC, with its connected IO modules, is programmed to monitor, control and regulate the heating, ventilation and other systems, as described earlier, either through the direct connected sensors and actuators or via gateways to wireless sensors and energy meters.

10.3 Data acquisition software

The data acquisition software consists of the following:

- Schneider Vijeo Citect: V7.20 [Supervisory Control and Data Acquisition (SCADA) – GUI software]
- Schneider OFS server: V3.34 [OPC data server – communication driver between PLC and SCADA software]
- Schneider Vijeo Historian: V4.30 [Data logger to Microsoft SQL server]
  - Microsoft SQL server [SQL database for data logged Vijeo Citect Tags]
- Schneider Unity Pro M: V5.0 [PLC programming software]
- Team Viewer [Remote access software for access through the internet]

Data to/from the PLC and SCADA software (Vijeo Citect V7.20) moves through the OPC server (OFS server V3.34) which acts as a communications driver between the PLC and the SCADA software. See Figure 32.

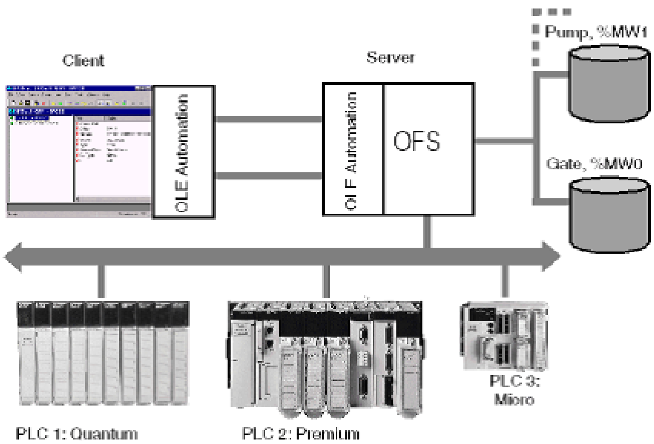


Figure 32 *The OFS interface between PLC and SCADA client.*

Data that has to be logged and saved for historical analysis are chosen in Vijeo Citect and configured in Vijeo Historian which acts as a SQL Server client and selected meter-, sensor- and alarm- data are stored for extended periods, independently of a SCADA system, in an "Historian" SQL database for later access and historical analysis. See Figure 33.

Data logged to the Historian can be accessed directly from the host SQL server database or from the Excel client.

10.4 Backup system

The data logging system in Sisimiut have several weak points, including easy write access from within the house, dependency on a consumer range

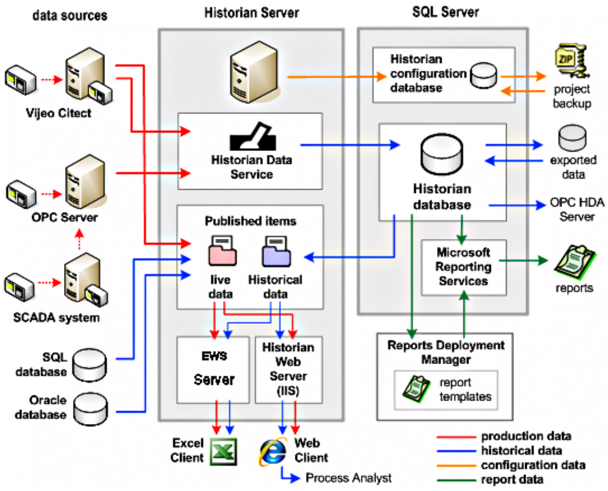


Figure 33 *Vijeo Historian server-based architecture to collect and redistribute data.*

laptop, a non-mirrored hard drive with all the risks that this implies (disk failures, theft, fire), and others. Moreover, the temperature in the room with the boiler used for the PLC system and the data logging, is high and certainly adds to the risk of hardware failures (and especially disk failures). High risk or not, backup of data is essential, and a complete backup of the database is being taken every month. Throughout most of 2012, an incremental mirroring was running but due to occasional Internet connection failures from the house, the mirroring would stall and have to be re-initiated manually. Now a complete backup is transferred every month. This has been configured by Ole Brandt.

11 Experimental planning

For analyzing the heat dynamics of a building, experiments with the heat input is central. A module to "Unity Pro M" has been written by Jakob Nørby to schedule open/close signals to floor heating valves in the guest apartment (5 loops) plus the scullery (1 loop). The 6 floor heating strings are controlled individually and for each 30 minutes. Values for 672 time steps can be set, corresponding to an experimental plan of 14 days. The module can be controlled both directly through the "Unity Pro M" interface and using an Excel macro also written by Jakob Nørby.

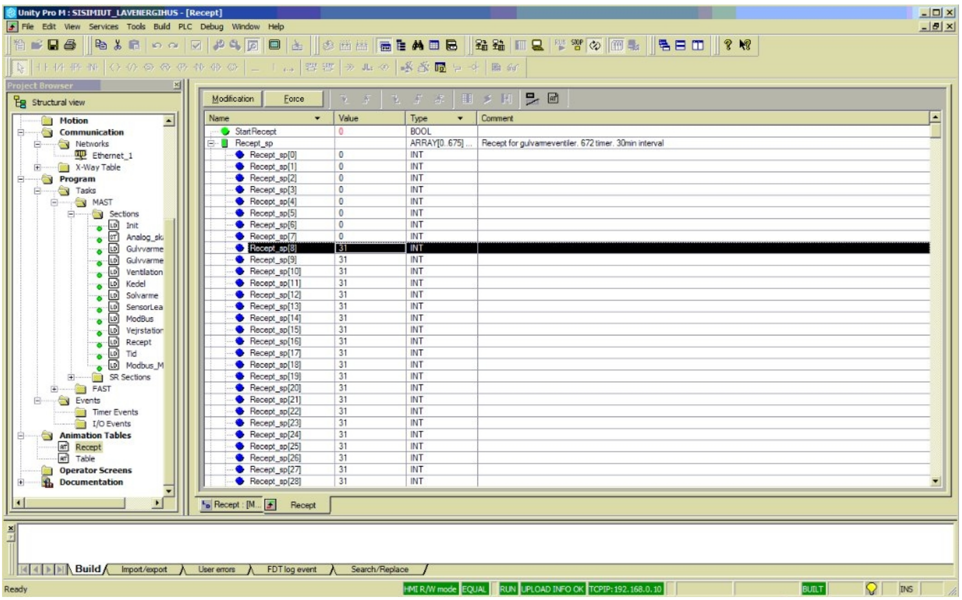


Figure 34 *The Unity Pro M interface to the module implementing planned floor heating in the guest apartment.*

11.1 Using Unitiy Pro M

To use the Unity Pro M interface do the following:

- Open Unity Pro M from the “Start” menu choosing `sisimiut_lavenergihus.stu`.
- In Unity Pro M, click PLC -> Connect.
- In Project Browser, double click Project -> Animation Tables -> Recept.

Figure 34 shows a screendump of the interface. The value `StartRecept` controls if the module is active or not. `Recept_sp` contains the schedule to be used. The signal is binary and given as a sum of decimal values in Table 2. To have no floor heating in the listed rooms, write 0. To have heating in say the living room and the small room, write 5. To have heating in the whole guest apartment and in the scullery, write 63. In Figure 34 the plan implemented means no heating for 3.5 hours, then heating in all the rooms in the guest apartment but not in the scullery. `sp[0]` is not used. If the pointer is “0” when the module is started, it will immediately switch to 1. When `StartRecept` is set to 1, any other control of floor heating in the rooms than listed in Table 2 is overruled. To edit the fields, make sure to have the Modifications button activated.

Table 2 *The elements to control with the experimental planning module.*

Bit	Valve	Room	Decimal value
0	`A01_MG07`	Living room	1
1	`A01_MG08`	Corridor	2
2	`A01_MG09`	Small room	4
3	`A01_MG10`	Large room	8
4	`A01_MG11`	Bathroom	16
5	`A01_MG12`	Scullery	32

The binary series can be seen and edited directly by pressing Shift-F3. Press F3 to edit in decimal values again.

11.2 Using MS Excel

In stead of typing in the experimental plan manually, it is possible to read a column of entries from Excel. This enables the user to generate the experimental plan with other software and feed it to the controller.

The spread sheet to use is called "`Recept parametre.xls`" and is located in "`C:\Sisimiut\OFS`". A copy should be edited in stead of the original. A screen dump of the interface is seen in Figure 35.

Do the following to use the Excel interface to implement an experiment plan:

- Write the values to submit to the PLC in the "Write" column.
- Press "Start".
- Pres "Write". The values in the Write column should now be copied to the Read column. If not, something went wrong in the communication with the PLC.
- Go to the Unity Pro M interface and start the experiment by setting `StartRecept` to 1 whenever you want.

The user does not need to use the "Stop" button which may make Excel crash. If that happens, it has no consequences for the PLC. Also when copying hundreds of elements, Excel may crash. One may need to copy only about 200 at a time.

12 Data extraction

Several methods are available for extraction of data from the system, and they will be described in this section. Most of the methods access the server

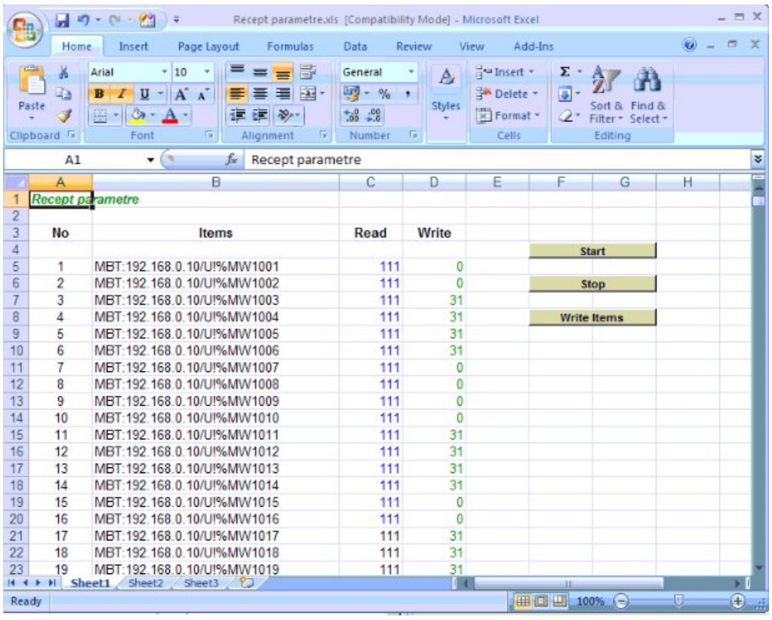


Figure 35 *The Excel interface, "*`Recept parametre.xls`*", to the experimental planning module.*

in Sisimiut directly. However, this is not advised. Using the backup server at DTU to access the data is faster unless the user is physically in the low energy house and can avoid using the Internet, it is free of the expensive charge on data transfer in Greenland, it does not risk blocking the Internet connection in the low energy house where there is a limit on monthly data transfer, and maybe most importantly, the user does not risk to delete data on the server in the low energy house. On how to extract data from the backup server, go to Section 12.3.

12.1 Data extraction using the PLC GUI

From within the PLC system overview, it is possible to extract recordings of weather, floor heating, and temperature measurements in the guest apartment. For weather data, click the menu box "Vejr", for the others, click "Trend". Under "Trend" one can choose between "Gulvvarme", "Gæstebolig" and "Gæstebolig temp". After activation of one of these, plots will show up of relevant data, and one can choose the period to consider. By clicking "Save to file" one can save the data to an Excel or text file on the server. This can now be transferred with e.g. the file transfer facility in Teamviewer.

When choosing to export to a text file, one will obtain a table with commas as decimal points and white spaces as field separator. The encoding of this file will be utf-16. At least in Linux/Unix systems it may be necessary to convert this into utf-8. `iconv` can be used for this

```
$ iconv -f UTF-16 -t UTF-8 oldfile.txt > newfile.txt
```

In **R** the file can now be read with

R Example 12.1.

```r
flh <- read.table("newfile.txt", header = TRUE, dec = ",")
```

The time stamp written to the file is in decimal days after Jan 1st 1900 00:00 UTC.

Only a very limited selection of the total data can be extracted in this way. The data obtained in the different sections is listed in Table 3.

Table 3 *The data series that can be extracted from the gui.*

"Gulvvarme" (Floor heating)
A01_FM01-A01_FM06, A01_FR01, A01_RT07, A01_MG07 - A01_MG12
"Gæstebolig" (Guest apartment)
A01_TS01 - A01_TS12, A01_PI01, A01_PI02, C01_TT01, C01_VU01_drift
"Gæstebolig temp" (Guest apartment temperature)
A01_RU01-A01_RU05, A01_RU01_sp - A01_RU05_sp, A01_RU11, A01_RU12
"Vejr" (Weather)
A01_UE01, A01_VH01, A01_VR01, A01_LU01

12.2 Data extraction from the MSSql server

Data can be fetched directly from the MSSql server in Sisimiut by – on the local system – starting the tool called "Import and export data (32 bit)".

1. Choose a Data Source

   Data source: SQL Server Native Client 10.0

   Server name: `LP-14444\VIJEOHISTORIAN`

   Authentication Use SAL Server Authentication

   Database: SisimiutData

2. Choose a Destination Destination: Flat File Destination File name: <you chose> Locale: English (United States), unicode

   Format: Delimited Text qualifier: <none>

3. Confgure Flat File Destination Row delimeter: CRLF Column delimeter: Comma , Per default, data will be appended to the destination file. Go to “Edit Mappings...” to edit this and other settings.

4. Specify Table Copy or Query Copy data from one or more tables or views.

5. Save and Run “Package Run” immediately.

when exporting tags, “`^A`” and “`^B`” must be replaced. In Emacs, C-q C-a, C-q C-b are keystrokes representing those characters. This is again an encoding issue.

12.3 Using the SQL server at DTU

The backup facility (Section 10.4) provides a fast SQL server located at DTU with the data. From within the DTU network, this server can be reached with any SQL client, given that one has an account on the server with read access. This is the recommended way to access the data. In **R**, functions have been written based on the RODBC library. Say, one wants to fetch the data from the room temperature in the bathroom and the registrations of presence in the living room (both in the guest apartment) in the period from February 20 to March 13 2012. This is done with:

R Example 12.2.

```r
names <- c("A01_PI01", "A01_RU04")
data.raw <- fetch.sensor(name = names, from = "2012-02-20",
    to = "2012-02-21")
```

The database has two tables, one for decimal measurements called `NumericSamples` and one with binary measurements called `DigitalSamples`. `fetch.sensor` looks up where to find the given sequences, creates the SQL queries and fetches the data. The SQL commands executed by `fetch.sensor` in this case are

```sql
SELECT Tags.TagName, NumericSamples.TagID, dbo.ToDate(
   NumericSamples.SampleDateTime) AS SampleDateTime,
   NumericSamples.SampleValue, NumericSamples.QualityID
   FROM Tags INNER JOIN (NumericSamples INNER JOIN
   Qualities ON NumericSamples.QualityID = Qualities.ID )
    ON Tags.ID = NumericSamples.TagID WHERE (
   SampleDateTime > dbo.ToBigInt('2012-02-20')) and  (
   SampleDateTime < dbo.ToBigInt('2012-02-21')) and
   TagName in ('MyCluster.plc_A01_RU04') ORDER BY
   SampleDateTime ASC
```

```
SELECT Tags.TagName, DigitalSamples.TagID, dbo.ToDate(
   DigitalSamples.SampleDateTime) AS SampleDateTime,
   DigitalSamples.SampleValue, DigitalSamples.QualityID
   FROM Tags INNER JOIN (DigitalSamples INNER JOIN
   Qualities ON DigitalSamples.QualityID = Qualities.ID )
    ON Tags.ID = DigitalSamples.TagID WHERE (
   SampleDateTime > dbo.ToBigInt('2012-02-20')) and  (
   SampleDateTime < dbo.ToBigInt('2012-02-21')) and
   TagName in ('MyCluster.plc_A01_PI01') ORDER BY
   SampleDateTime ASC
```

`fetch.sensor` returns a list of dataframes. The names of the dataframes are the names of the measurements, in this case `A01_PI01` and `A01_RU04`. These data.frames contain two columns each, one called `time` with time stamps in `POSIXct` format, and one called `values` containing the actual measurements. Each series of measurements have their own time column because they are not necessarily identical. If one wants to obtain shared time stamps, a filter must be applied. Such filters have also been implemented in **R**.

12.4 Using extracted data

When the raw data comes from the database, it needs some processing before it can be used for many time series applications. This is due to asynchronous sampling of signals and uneven sampling periods. Often the user will want to interpolate or average to some fixed timestamps before modeling the data.

Normally all measurements are logged every 30 seconds. The system uses a so-called "deadband" to avoid redundant sampling. That is if a signal has the same value plus/minus the deadband at the succeeding measurement, the measurement will not be logged. This has to be taken into account for interpolation or averages to be correct. The deadband is set to zero for all signals but in case the signal is exactly constant, it will still influence. This is often the case for e.g. flow measures (when there is no flow) and of course the binary signals. A function called `revive.band` has been written to re-construct the signal with 30 second resolution.

R Example 12.3.

```r
## revive one signal
A01PI01.revived <- revive.band(data.raw$A01_PI01)
## revive multiple signals
data.revived <- lapply(data.raw, revive.band)
## revive multiple signals using multithreading
data.revived <- mclapply(data.raw, revive.band, mc.cores = 2)
```

After ”reviving” the signals, the data is ready to be interpolated, averaged, or processed in some other way in order to synchronize sampling and obtaining the sampling rate that the user wants. How to carry out this step depends completely on the processing wanted. A few different schemes have been implemented in an **R** function called `mergedata`.

- Interpolation between nearest points is available with the `approx` function in **R**. This method has the serious backdraw that it potentially disregards most of the data. For instance, if measurements are taken every 30 seconds, and one wants a 30 minute resampling, only 2 out of 60 measurements are used.
- Averaging the raw data is the second option. Then all of the 60 data points in the example above is used. However, in case of uneven distance between sampling times in raw data, they are not weighted correctly. This can be a serious problem in situations where sampling rates are erratic and/or signals are non-linear.
- The last option implemented interpolates to a specified sampling rate first, and then it averages. If interpolating to 30 seconds before averaging, all data points should be used, and the averaging can correctly use even weighting of the interpolated points.

Here follows examples on how to obtain sub-sampling taking into account these issues:

R Example 12.4.

```
## a series of time stamps to average to
synctime <- seq(from = as.POSIXct("2012-02-20", tz = "UTC"),
    to = as.POSIXct("2012-01-21", tz = "utz"), by = 15 *
        60)
## interpolation using nearest two points.
data.sync.15min <- mergedata(data.revived, mergeby = "time",
    time = synctime, approxfun = approx, parallel = TRUE)
## averaging over +/-7.5 minutes
data.sync.15min <- mergedata(data.revived, mergeby = "time",
    time = synctime, approxfun = resample, parallel = TRUE,
    h = 15 * 60 - 1, kernel = "mean", pastonly = FALSE,
    na.rm = TRUE)
## averaging over +/-7.5 minutes insuring correct
## weighting.
data.sync.15min <- mergedata(data.revived, mergeby = "time",
    time = synctime, approxfun = resample, parallel = TRUE,
```

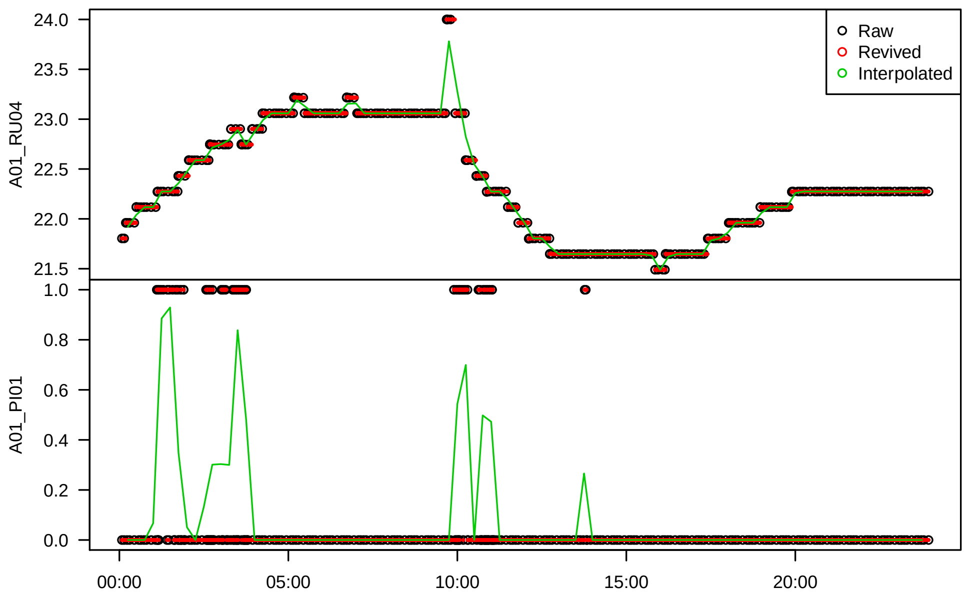


Figure 36 *Example on raw (black), revived (red), and interpolated (green) data from a sensor logged in the numeric table, and a sensor in the digital table of the database.*

```
h = 15 * 60 - 1, kernel = "mean.int", int.step = 30,
pastonly = FALSE, na.rm = TRUE)
```

The `h` argument is the width of the interval considered. The `pastonly` argument decides whether the algorithm should only look back in time to evaluate the filtered value. This should be set to `TRUE` if one wants to simulate real-time modeling. `parallel` controls whether multithreading should be enabled, and `na.rm` controls if missing data points should simply be discarded or result in a missing point. The latter gets very important as the `h` increases since there will often be at least one missing data point in say one day.

Figure 36 plots the obtained data using these steps resulting in interpolated signals of 15 minute resolution. From the raw (black) data to the revived (red) the sampling frequency is ensured to be constant by repeating preceding values. The green lines are interpolations to sample times predefined by the user. The green signals can be compared because they share sample times.

Table 4 in Appendix can be read into **R**, and used to select sensors to retrieve. The following example fetches all data related to the floor heating system in the guest apartment:

R Example 12.5.

```r
sensor.names <- sensors$Tag[sensors$Group == "Floor heating" &
    sensors$Apartment == "Guest"]
```

which can then be retrieved using `fetch.sensor`. Actually, `fetch.sensor` uses the column ”`db.table`” to determine which table in the database to retrieve the signals from.

13 Conclusions

A low-energy house in Sisimiut, Greenland has been equipped with measurement and control equipment enabling detailed surveillance and experiments related to heat dynamics of the building, influence of occupant behavior, and storage strategies of power generated solar radiation.

Different systems in the building have been described, and examples on measurements from the data acquisition system have been given. This includes consumption variables, the heating systems, the solar thermal system, occupancy indicators, and the weather station. In the description, several issues about the data series were addressed. In the treatment of the temperature measurements from the building, an example on principal component analysis was given indicating dynamical properties in one apartment of the house.

The data acquisition and control unit can be used to execute planned experiments as well. It was described how to do this for experiments with the floor heating system in an apartment available for research.

Several methods of data extraction were described, and **R** functions have been developed to handle and process the data for statistical modeling.

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A List of sensors

Table 4 provides an overview of the sensors installed in the house. The table is not complete. For each sensor it contains the following fields:

Tag	Tag name in the database.
Description	a few keywords describing the sensor.
Unit	The unit of the data.
Apartment	The apartment it relates. “Rent”, “Guest”, or “Common”.
db.table	The table in which it is found in the database.
Group	A grouping of the sensors that can be used when retrieving data.
Sensor	The type of sensor providing the measurements.

Table 4 *List of the sensors in the building and their names in the database.*

Tag	Description	Unit	Apartment	db.table	Group	Sensor
`A02_CP01`	Circulation pump from boiler	start/stop	Common	digital	Heating circuit	
`A02_Drift`	Circulation pump, error		Common	digital	Heating circuit	
`A02_FM01`	Flow, oil to boiler	Always 0	Common	numerical	Consumption	
`A02_FM01_TRIP`	Trip cumulative flow, oil to boiler	l	Common	numerical	Consumption	
`A02_FM01_SUM`	Cumulative flow, oil to boiler	l	Common	numerical	Consumption	
`A02_FR01`	Temperature boiler, forward	$^\circ$C	Common	numerical	Boiler	Sensonic LTT420S (0-100°C)
`A02_OD01`	Boiler	Start/stop	Common	digital	Boiler	
`A02_RT01`	Temperature boiler water, before heat exchanger	$^\circ$C	Common	numerical	Boiler	Sensonic LTT420S (0-100°C)
`A02_RT02`	Temperature boiler water, after heat exchanger	$^\circ$C	Common	numerical	Boiler	Sensonic LTT420S (0-100°C)
`A02_STOP`	Boiler stop	1=stop	Common	digital	Boiler	
`A04_FM01`	Flow, hot water from tank	?	Common	numerical	Water cons	Brunata HGQ1qp 1,2 m3/h
`A04_FM01_SUM`	Cumulative hot water consumption	l	Common	numerical	Water cons	
`A04_FR01`	Temperature, from boiler to spiral, forward	$^\circ$C	Common	numerical	Water cons	Sensonic LTT420S (0-100°C)
`A04_MV01`	Control valve, heat coil *(?)*		Common	digital	Domestic water tank	
`A04_RT01`	Temperature, spiral to boiler, return	$^\circ$C	Common	numerical	Domestic water tank	Sensonic LTT420S (0-100°C)
`A04_TF01`	Temperature, tank, top	$^\circ$C	Common	numerical	Domestic water tank	
`A04_TF02`	Temperature, tank	$^\circ$C	Common	numerical	Domestic water tank	
`A04_TF03`	Temperature, tank, bottom	$^\circ$C	Common	numerical	Domestic water tank	
`A01_MG01`	Hall	On/off	Common	digital	Floor heating	Vox
`A01_MG02`	Bathroom	On/off	Rent	digital	Floor heating	Vox
`A01_MG03`	Large room	On/off	Rent	digital	Floor heating	Vox
`A01_MG04`	Small room	On/off	Rent	digital	Floor heating	Vox
`A01_MG05`	Corridor	On/off	Rent	digital	Floor heating	Vox
`A01_MG06`	Living room	On/off	Rent	digital	Floor heating	Vox
`A01_MG07`	Living room	On/off	Guest	digital	Floor heating	Vox
`A01_MG08`	Corridor	On/off	Guest	digital	Floor heating	Vox
`A01_MG09`	Large room	On/off	Guest	digital	Floor heating	Vox
`A01_MG10`	Small room	On/off	Guest	digital	Floor heating	Vox
`A01_MG11`	Bathroom	On/off	Guest	digital	Floor heating	Vox
`A01_MG12`	Scullery	On/off	Common	digital	Floor heating	Vox

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Table 4 – continued from previous page

Tag	Description	Unit	Apartment	db.table	Group	Sensor
A01_FR01	Combined forward flow temp	°C	Common	numerical	Floor heating	
A01_CP01	Combined inflow pump	Binary	Common	digital	Floor heating	
A01_FM01	Scullery, flow	l/h	Common	numerical	Floor heating	Brunata HGQ1qp 1,2 m3/h
A01_FM01_SUM	Scullery, flow		Common	numerical	Floor heating	
A01_FM02	Bathroom, flow	l/h	Guest	numerical	Floor heating	Brunata HGQ1qp 1,2 m3/h
A01_FM02_SUM	Bathroom, flow		Guest	numerical	Floor heating	
A01_FM03	Large room, flow	l/h	Guest	numerical	Floor heating	Brunata HGQ1qp 1,2 m3/h
A01_FM03_SUM	Large room, flow		Guest	numerical	Floor heating	
A01_FM04	Small room, flow	l/h	Guest	numerical	Floor heating	Brunata HGQ1qp 1,2 m3/h
A01_FM04_SUM	Small room, flow		Guest	numerical	Floor heating	
A01_FM05	Corridor, flow	l/h	Guest	numerical	Floor heating	Brunata HGQ1qp 1,2 m3/h
A01_FM05_SUM	Corridor, flow		Guest	numerical	Floor heating	
A01_FM06	Living room, flow	l/h	Guest	numerical	Floor heating	Brunata HGQ1qp 1,2 m3/h
A01_FM06_SUM	Living room, flow		Guest	numerical	Floor heating	
A01_FM07	Hall, flow	l/h	Common	numerical	Floor heating	Brunata HGQ1qp 1,2 m3/h
A01_FM07_SUM	Hall, flow		Common	numerical	Floor heating	
A01_FM08	Bathroom, flow	l/h	Rent	numerical	Floor heating	Brunata HGQ1qp 1,2 m3/h
A01_FM08_SUM	Bathroom, flow		Rent	numerical	Floor heating	
A01_FM09	Large room, flow	l/h	Rent	numerical	Floor heating	Brunata HGQ1qp 1,2 m3/h
A01_FM09_SUM	Large room, flow		Rent	numerical	Floor heating	
A01_FM10	Small room, flow	l/h	Rent	numerical	Floor heating	Brunata HGQ1qp 1,2 m3/h
A01_FM10_SUM	Small room, flow		Rent	numerical	Floor heating	
A01_FM11	Corridor, flow	l/h	Rent	numerical	Floor heating	Brunata HGQ1qp 1,2 m3/h
A01_FM11_SUM	Corridor, flow		Rent	numerical	Floor heating	
A01_FM12	Living room, flow	l/h	Rent	numerical	Floor heating	Brunata HGQ1qp 1,2 m3/h
A01_FM12_SUM	Living room, flow		Rent	numerical	Floor heating	
A01_RT01	Scullery return temp	°C	Common	numerical	Floor heating	Sensonic LTT420S (0-100°C)
A01_RT02	Bathroom return temp	°C	Guest	numerical	Floor heating	Sensonic LTT420S (0-100°C)
A01_RT03	Large room return temp	°C	Guest	numerical	Floor heating	Sensonic LTT420S (0-100°C)
A01_RT04	Small room return temp	°C	Guest	numerical	Floor heating	Sensonic LTT420S (0-100°C)
A01_RT05	Corridor return temp	°C	Guest	numerical	Floor heating	Sensonic LTT420S (0-100°C)
A01_RT06	Living room return temp	°C	Guest	numerical	Floor heating	Sensonic LTT420S (0-100°C)
A01_RT07	Combined return temp	°C	Common	numerical	Floor heating	Sensonic LTT420S (0-100°C)
A01_RT08	Hall return temp	°C	Common	numerical	Floor heating	Sensonic LTT420S (0-100°C)
A01_RT09	Bathroom return temp	°C	Rent	numerical	Floor heating	Sensonic LTT420S (0-100°C)
A01_RT10	Large room return temp	°C	Rent	numerical	Floor heating	Sensonic LTT420S (0-100°C)

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Table 4 – continued from previous page

Tag	Description	Unit	Apartment	db.table	Group	Sensor
A01_RT11	Small room return temp	°C	Rent	numerical	Floor heating	Sensonic LTT420S (0-100°C)
A01_RT12	Corridor return temp	°C	Rent	numerical	Floor heating	Sensonic LTT420S (0-100°C)
A01_RT13	Living room return temp	°C	Rent	numerical	Floor heating	Sensonic LTT420S (0-100°C)
A01_RU01	Large room	°C	Guest	numerical	Room temperatures	Thermokon SR 04
A01_RU02	Small room	°C	Guest	numerical	Room temperatures	Thermokon SR 04
A01_RU03	Corridor	°C	Guest	numerical	Room temperatures	Thermokon SR 04
A01_RU04	Bathroom	°C	Guest	numerical	Room temperatures	Thermokon SR 04
A01_RU05	Living room	°C	Guest	numerical	Room temperatures	Thermokon SR 04
A01_RU06	Large room	°C	Rent	numerical	Room temperatures	Thermokon SR 04
A01_RU07	Small room	°C	Rent	numerical	Room temperatures	Thermokon SR 04
A01_RU08	Corridor	°C	Rent	numerical	Room temperatures	Thermokon SR 04
A01_RU09	Bathroom	°C	Rent	numerical	Room temperatures	Thermokon SR 04
A01_RU10	Living room	°C	Rent	numerical	Room temperatures	Thermokon SR 04
A01_RU11	Scullery	°C	Common	numerical	Room temperatures	Thermokon SR 04
A01_RU12	Hall	°C	Common	numerical	Room temperatures	Thermokon SR 04
C01_RU01	Living room, 1 from top	°C	Guest	numerical	Std temp meas	Thermocouple, type T, transmitter: Seneca K121
C01_RU02	Living room, 2 from top	°C	Guest	numerical	Std temp meas	Thermocouple, type T, transmitter: Seneca K121
C01_RU03	Living room, 3 from top	°C	Guest	numerical	Std temp meas	Thermocouple, type T, transmitter: Seneca K121
C01_RU04	Living room, 4 from top	°C	Guest	numerical	Std temp meas	Thermocouple, type T, transmitter: Seneca K121
C01_RU05	Living room, 5 from top	°C	Guest	numerical	Std temp meas	Thermocouple, type T, transmitter: Seneca K121
C01_RU06	Living room, 6 from top	°C	Guest	numerical	Std temp meas	Thermocouple, type T, transmitter: Seneca K121
A01_PI01	PIR, Living room	1=activity	Guest	digital	Occupancy	PEHA 482 FU-BM DE
A01_PI02	PIR, Corridor	1=activity	Guest	digital	Occupancy	PEHA 482 FU-BM DE
A01_TS01	Door, scullery	1=closed	Guest	digital	Occupancy	Enocean STM 250
A01_TS02	Door, terrace	1=closed	Guest	digital	Occupancy	Enocean STM 250
A01_TS03	Door, hall	1=closed	Guest	digital	Occupancy	Enocean STM 250
A01_TS04	Door, scullery	1=closed	Rent	digital	Occupancy	Enocean STM 250
A01_TS05	Door, terrace	1=closed	Rent	digital	Occupancy	Enocean STM 250
A01_TS06	Door, hall	1=closed	Rent	digital	Occupancy	Enocean STM 250
A01_TS07	Door, back	1=closed	Common	digital	Occupancy	Enocean STM 250
A01_TS08	Door, front	1=closed	Common	digital	Occupancy	Enocean STM 250
A01_TS09	Window, large room	1=closed	Guest	digital	Occupancy	Enocean STM 250
A01_TS10	Window, small room	1=closed	Guest	digital	Occupancy	Enocean STM 250
C01_CO01	CO_2 out	ppm	Guest	numerical	Occupancy	
C01_FM01	Flow in	m3/h	Common	numerical	Ventilation	
C01_FM02	Flow out	m3/h	Common	numerical	Ventilation	

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Table 4 – continued from previous page

Tag	Description	Unit	Apartment	db.table	Group	Sensor
C01_FR01	Temp before heat surface ??		Common	numerical	Ventilation	Sensonic LTT420S (0-100)
C01_TT01	Cooker hood, el current	A	Rent	numerical	Ventilation	Carlo Gavazzi E83-2050
C01_TT02	Cooker hood, el current	A	Guest	numerical	Ventilation	Carlo Gavazzi E83-2050
C01_TT03	Pressure drop *heat exchanger*,out		Common	numerical	Ventilation	
C01_UD02	Temperature,outtake, after heat exchanger	°C	Common	numerical	Ventilation	
C01_VI01	Intake	1=On,0=off	Common	digital	Ventilation	
C01_VI01_AO	Intake, speed		Common	numerical	Ventilation	
C01_VI01_drift	Intake, error		Common	digital	Ventilation	
C01_VU01	Outtake	1=On,0=off	Common	digital	Ventilation	
C01_VU01_AO	Outtake, speed		Common	numerical	Ventilation	
C01_VU01_drift	Outtake, error		Common	digital	Ventilation	
C01_HY01	Rel. humidity, Outtake	%	Guest	numerical	Ventilation	
C01_HY02	Rel. humidity, Outtake	%	Rent	numerical	Ventilation	
C01_HY03	Rel. humidity, Outtake, before heat exchange	%	Common	numerical	Ventilation	
C01_HY04	Rel. humidity, Outtake, after heat exchange	%	Common	numerical	Ventilation	
C01_HY05	Rel. humidity, Intake, before heat exchange	%	Common	numerical	Ventilation	
C01_HY06	Rel. humidity, Intake, after heat exchange	%	Common	numerical	Ventilation	
C01_HY10	Rel. humidity, Basement pos. 1	%	Common	numerical	Basement	
C01_HY11	Rel. humidity, Basement pos. 2	%	Common	numerical	Basement	
C01_HY12	Rel. humidity, Basement pos. 3	%	Common	numerical	Basement	
C01_HY13	Rel. humidity, Basement pos. 4	%	Common	numerical	Basement	
C01_IN01	Temp, intake, after heat exchange, before after heating	°C	Common	numerical	Ventilation	
C01_UD01	Temp, outtake, before heat exchange	°C	Common	numerical	Ventilation	
C01_IN02	Temp, intake, after heat exchange and after heating	°C	Common	numerical	Ventilation	
C01_IN03	Temp, intake, before heat exchange and after heating	°C	Common	numerical	Ventilation	
C01_MV01	Control valve, heat surface		Common	numerical	Ventilation	
C01_RT01	Return temp, heat surface	°C	Common	numerical	Ventilation	Sensonic LTT420S (0-100)
C01_SM01	Heat exchanger damper		Common	digital	Ventilation	
C01_TF10	Temp, Basement pos. 1	°C	Common	numerical	Basement	

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Table 4 – continued from previous page

Tag	Description	Unit	Apartment	db.table	Group	Sensor
C01_TF11	Temp, Basement pos. 2	°C	Common	numerical	Basement	
C01_TF12	Temp, Basement pos. 3	°C	Common	numerical	Basement	
C01_TF13	Temp, Basement pos. 4	°C	Common	numerical	Basement	
A01_X01	Floor heating, sum	kWh	Common	numerical	Floor heating	
A01_X02	Floor heating, instant	kW	Common	numerical	Floor heating	
A01_X03	Floor heating, flow, sum	m3	Common	numerical	Floor heating	
A01_X04	Floor heating, flow, instant	l/h	Common	numerical	Floor heating	
A01_X05	Floor heating, Temp, before	°C	Common	numerical	Floor heating	
A01_X06	Floor heating, Temp, return	°C	Common	numerical	Floor heating	
A01_X10	Electricity, cumulative	kWh	Rent	numerical	Consumption	
A01_X11	Electricity, cumulative	kWh	Guest	numerical	Consumption	
A01_X12	Electricity, cumulative	kWh	Common	numerical	Consumption	
A03_CP01	Solar circulation pump	Start/stop	Common	digital	Solar thermal	
A03_CP02	Buffer Circulation pump	Start/stop	Common	digital	Solar thermal	
A03_FM01	Flow, solar panel		Common	digital	Solar thermal	
A03_FM01_SUM	Cumulative flow, solar panel		Common	digital	Solar thermal	
A03_FR01	Temperature, glucola to solar	°C	Common	numerical	Solar thermal	Sensonic LTT420S (0-100)
A03_FR02	Temperature, glucola to buffer	°C	Common	numerical	Solar thermal	Sensonic LTT420S (0-100)
A03_FR03	Temperature, after radiator	°C	Common	numerical	Solar thermal	Sensonic LTT420S (0-100)
A03_MV01	Control valve, solar heat		Common	numerical	Solar thermal	
A03_MV02	Control valve, buffer		Common	digital	Solar thermal	
A03_MV03	Control valve, radiator bypass		Common	digital	Solar thermal	
A03_MV04	*Control valve, circulation*		Common	digital	Solar thermal	
A03_RT01	Temperature, glucola after solar	°C	Common	numerical	Solar thermal	Sensonic LTT420S (0-100)
A03_RT02	Return temp, after buffer	°C	Common	numerical	Solar thermal	Sensonic LTT420S (0-100)
A03_TF01	Temperature, buffer, top	°C	Common	numerical	Buffer tank	
A03_TF02	Temperature, buffer, 2nd from top	°C	Common	numerical	Buffer tank	
A03_TF03	Temperature, buffer, 3rd from top	°C	Common	numerical	Buffer tank	
A03_TF04	Temperature, buffer, bottom	°C	Common	numerical	Buffer tank	
Solvarme_kW			Common	numerical	Solar thermal	
A03_X01	Energy, sum	kWh	Common	numerical	Solar thermal	
A03_X02	Power	kW	Common	numerical	Solar thermal	
A03_X03	Flow, sum		Common	numerical	Solar thermal	
A03_X04	Flow, instant		Common	numerical	Solar thermal	
A03_X05	Temp, before	°C	Common	numerical	Solar thermal	
A03_X06	Temp, return	°C	Common	numerical	Solar thermal	

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Table 4 – continued from previous page

Tag	Description	Unit	Apartment	db.table	Group	Sensor
A03_X11	Excess energy, sum	kWh	Common	numerical	Solar thermal	
A03_X12	Excess energy, Instant	kW	Common	numerical	Solar thermal	
A03_X13	Excess flow, sum		Common	numerical	Solar thermal	
A03_X14	Excess flow, Instant		Common	numerical	Solar thermal	
A03_X15	Excess temp, before	°C	Common	numerical	Solar thermal	
A03_X16	Excess temp, return	°C	Common	numerical	Solar thermal	
A04_X01	Water in, sum	kWh	Common	numerical	Water cons	
A04_X02	Water flow in, instant	m3/h	Common	numerical	Water cons	
A04_X03	Water flow in, sum	m3	Common	numerical	Water cons	
A04_X04	Water flow in, instant	?	Common	numerical	Water cons	
A04_X05	Water temp in, in	°C	Common	numerical	Water cons	
A04_X06	Water temp out	°C	Common	numerical	Water cons	
A04_X10	Hot water meter	?	Common	numerical	Water cons	
A04_X11	Extra energy to hot water	kWh	Common	numerical	Water cons	
C01_X01	Ventilation heating, sum	kWh	Common	numerical	Vent heat circuit	
C01_X02	Ventilation heating, Instant	kW	Common	numerical	Vent heat circuit	
C01_X03	Ventilation heating flow, sum		Common	numerical	Vent heat circuit	
C01_X04	Ventilation heating flow, instant		Common	digital	Vent heat circuit	
C01_X05	Ventilation heating temp, before	°C	Common	numerical	Vent heat circuit	
C01_X06	Ventilation heating temp, after	°C	Common	numerical	Vent heat circuit	
A01_VH01_middel	Wind speed, ten minutes mean	m/s	Common	numerical	Weather	
A01_VH01	Wind speed, instant	m/s	Common	numerical	Weather	Young Yo05103L-45
A01_UE01	Outdoor temperature	°C	Common	numerical	Weather	MB teknik 2.1280.00.141
a01_vr01_middel	Wind direction (from N), ten minutes mean	°C	Common	numerical	Weather	
A01_VR01	Wind direction (from N)	°C	Common	numerical	Weather	Young Yo05103L-45
A01_LU01	Global solar radiation	W/m2	Common	numerical	Weather	MB teknik 7.1415.09.041
TWC	Temperature, corrected for chill factor	°C	Common	numerical	Weather	
C01_TF01	Temp, paper insulation 1	°C	Common	numerical	Paper insulation	Thermokon LCN-FTK
C01_TF02	Temp, paper insulation 2	°C	Common	numerical	Paper insulation	Thermokon LCN-FTK
C01_TF03	Temp, paper insulation 3	°C	Common	numerical	Paper insulation	Thermokon LCN-FTK
C01_TF04	Temp, paper insulation 4	°C	Common	numerical	Paper insulation	Thermokon LCN-FTK
C01_HY07	Humid, paper insulation 1	%	Common	numerical	Paper insulation	Thermokon LCN-FTK
C01_HY08	Humid, paper insulation 2	%	Common	numerical	Paper insulation	Thermokon LCN-FTK
C01_HY09	Humid, paper insulation 3	%	Common	numerical	Paper insulation	Thermokon LCN-FTK

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Table 4 – continued from previous page

Tag	Description	Unit	Apartment	db.table	Group	Sensor
C01_HY10	Humid, paper insulation 4	%	Common	numerical	Paper insulation	Thermokon LCN-FTK

B Network overview

The following page features an overview of the network infrastructure in the building.

Sisimiut lavenergihus. PLC og Scada netværk

Software versioner:
Windows 7 Enterprise
Unity Pro M : V5.0
Vijeo Citect: V7.20
OFS: V3.34
Vijeo Historian: V4.30
TeamViewer. v6

Licens info:
Vijeo Citect: 500 tags
Vijeo Historian: 500 tags
Full licens : 1
Web client: 2
SN: 0479 – 97739

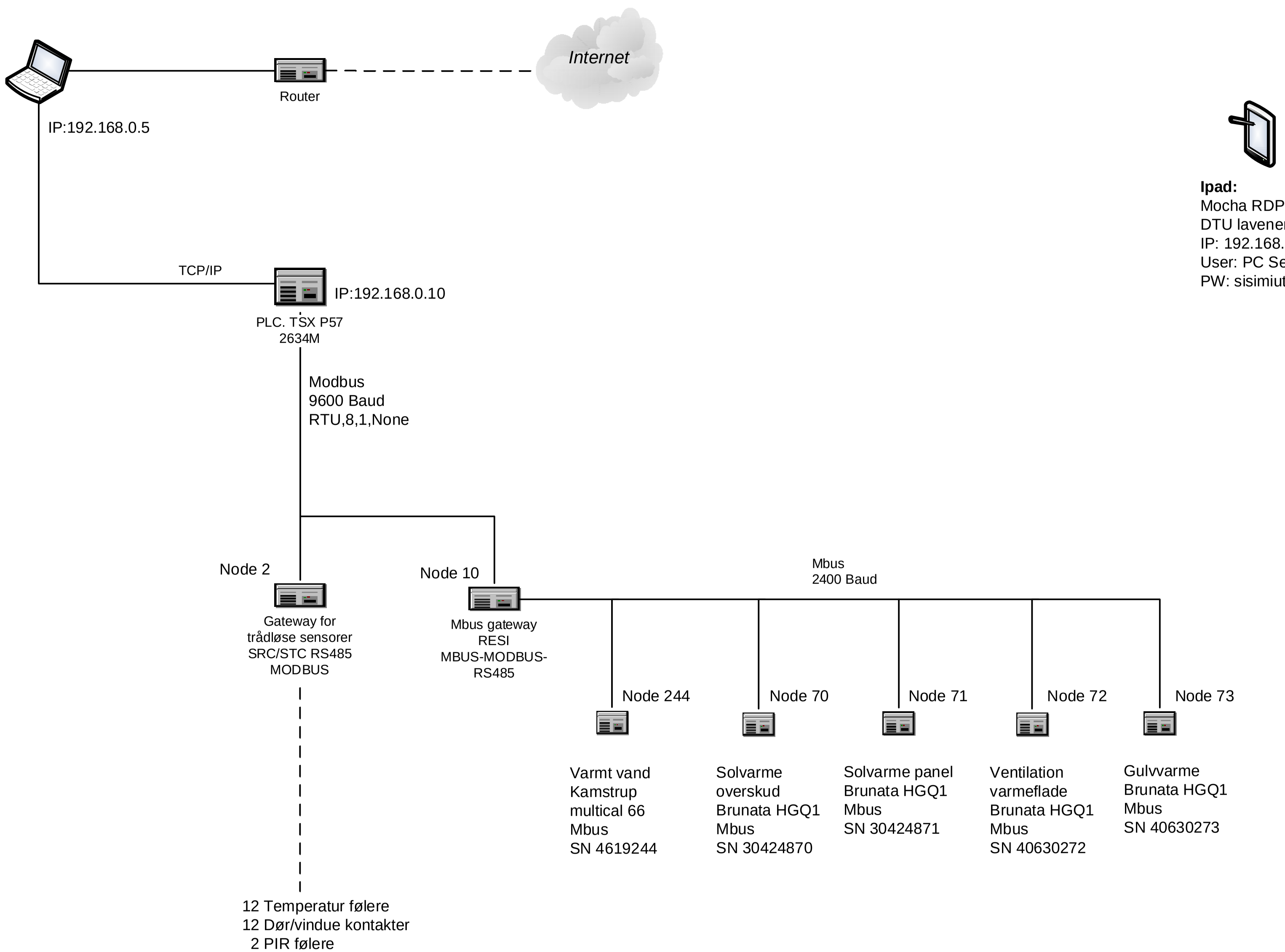
Unity SN: 21105101086

Team Viewer Login:
ID: 564 027 677
PW: Sisimiut8607

PC Login:
PC navn: LP-14444
User: PC Service Technician
PW: sisimiut

Historian client Login:
Server: LP-14444
Database: Historian
User name: user
PW: user

WLAN:
SSID: ArtekNet
Key: Anet4all@low!



Ipad:
Mocha RDP Login.
DTU lavenergihus
IP: 192.168.254.250
User: PC Service Technician
PW: sisimiut

Adresse:
Bolefhep Aqq. 36
3911 Sisimiut
Lejer: Laarseraq Skifte
Tlf: +299585901

SisimiutNetværk.vsd	Rev.0
Sisimiut lavenergihus Netværk	18.11.11